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ANOMALIES OF PIGMENTATION AMONG NATIVES OF NYASALAND.

A CONTRIBUTION TO THE STUDY OF ALBINISM*.

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I. *Classification.*

ON page 148 of Part I of the *Monograph on Albinism* by Pearson, Nettleship and Usher from the Department of Applied Statistics, University College, London (Dulau & Co.), 1911, Professor Karl Pearson remarks, after dealing with some cases of albinism reported by myself and embodied in that work, "It is impossible to study Dr Stannus's data without being impressed with the various grades of albinism to be found in the dark races." It is particularly with the wish of drawing attention to this point that I now publish notes on cases of albinism which have come under my notice since the appearance of the above monograph. Pearson notices that there appears to be a greater variation in the albinotic characters among dark-skinned peoples, and seems inclined to attribute it to the fact that the various lesser grades of albinism are more readily distinguished among them than among fair races. With this I agree, and, as my own cases will show, intermediate forms between more or less well-marked types are found in numbers. This is a matter which I think has largely escaped the observation of those who have published records of cases. I am of opinion that for this reason consideration of the observations made by a single individual on a number of cases from a single country is more likely to give a correct impression of the subject than a mass of material drawn from many sources.

The difficulty in defining albinism lies in the fact that short of a microscopical examination of all the tissues of the body it is impossible to say whether pigment is present or not. Dealing with the tissues more especially concerned in albinism,

* This paper formed part of a thesis presented for the degree of Doctor of Medicine at the University of London. [The absence of Dr Stannus in Nyasaland has thrown upon the Editor the responsibility of editing these pages for press. Names have not always been spelt uniformly in the type-written manuscript, and at various other points the Editor has badly needed Dr Stannus' help. The Editor has ventured to add a few footnotes in square brackets on topics, which he would much preferred to have previously discussed with the author. ED.]

that is, those tissues which normally contain sufficient pigment to be evident to the unaided eye, it has been found that, even when they appear to contain none to the unaided eye, on microscopical examination a certain amount of pigment may be present; such has been demonstrated in the case of the eye and hairs.

Pearson divides albinotic negroes into the following classes:

(I) Complete albino.

(II) The spotted (freckled) albino.

(III) The blue-eyed white-skinned negro with photophobia and nystagmus but not red pupils.

(IV) The yellow-eyed white-skinned negro.

(V) Xanthous negro.

(VI) The partial albino or piebald negro.

Considerable confusion I think has arisen over the matter of the colour of the eye, which in my opinion invalidates some descriptions and also probably the above classification. "Eyes said to have the pinkish colour common to albinos," "the eyes are pink," are expressions commonly found in reading descriptions. Again, Sir H. Johnston in referring to Nyasaland writes, "cases of Albinism when the hair is yellowish white, the iris of the eye pink and the body skin an unwholesome-looking, reddish white are not common." When I say that I have collected a very large number of albinos in that country and that I have never seen a case presenting this characteristic of the iris, I think it may be assumed that in this case as in some others a lack of precise observation has led Sir H. Johnston to make an incorrect statement.

The same is, I think, true of a number of the loose statements made by other persons. They know that in typical European albinos and in, say, white mice the eye is "pink," and when they see a native of Africa with white skin and hair in whom it is difficult to get a proper view of the eye owing to nystagmus and photophobia they assume that the "eye is pink."

Dr Turner in describing cases of albinism seen in S. Africa, does not specify the colour of the irides and pupil in individual cases but refers only in general terms to the peculiar pink colour of the pupil, yet from the context it is evident he is speaking of the red reflex obtained through the pupils with the use of artificial light, though Pearson does not make this point clear.

The point I wish to emphasize is that in all cases noted by myself, when seen in ordinary daylight the pupil appears black and there is no red colour seen through the pupils under these conditions as seen in European albinos. I believe this to be true of African albinos in general, though I do not altogether doubt the occurrence in rare instances of the other phenomenon. The explanation lies, I think, in the fact that absolute albinism of the eye in negroes is very rare and that the amount of pigmentation present is sufficient to prevent a large light entry and reflexion: that is to say, the number of complete negro albinos who

will come under Pearson's Class (I) is very small, and this type is not found in Nyasaland at all events. He may on the other hand be referring to the presence of a "red reflex" obtained during ophthalmoscopical examination *.

When examined with artificial light and ophthalmoscopic mirror, all those of my cases approaching complete albinism show a "red reflex," differing from the dull red grey in the normal native in being brighter and devoid of the element of grey to a variable extent; and in some the brightness being greater than in the ordinary European, simulating that in a European albino.

The reason of the absence of light reflex (red pupil) in daylight is I believe due to the impediment to sufficient light entry caused by pigment on the posterior surface of the iris as much as to light absorption by pigment in the choroid.

In all my cases approaching the condition of complete albinism the irides are of a liquid steel blue grey colour, in some associated with a peripupillary ring of orange colour.

This I find corresponds to the descriptions given by observers in other parts of Africa whose writings bear the impress of being the result of careful observation.

I have considered these points at some length as I do not feel that the working classification given by Pearson clearly defines itself.

In Class (III) what does "not red pupils" mean? Does it mean the pupil is not red in the sense that the white rat's is, or does the expression refer to cases in which no red reflex can be obtained with artificial light?

In which class are to be placed cases which though they give this red reflex, have blue irides, in (I) or (III)?

The brightness of the red reflex varies very considerably, and I shall therefore make out one class which includes all those cases with white skin, white and yellow white hair, pale blue grey irides which give with artificial illumination a red reflex of any degree as opposed to a grey one. I shall also include in the same group as a sub-class those albinos with the above characteristics in whom, in addition, there have developed spots of pigmentation, so called Spotted or Freckled Albinos; I do this because the condition is not uncommonly found in the albinos of this country beyond the age of infancy.

I think it may be of use to make a group under Class (IV), that is, cases with yellow eyes but white skin.

* [I think Dr Stannus is incorrect at this point, the red reflex from negro albino eyes was noted in a number of cases even before the invention of the ophthalmoscope and has frequently been noted since by trained observers not using artificial light. Our albino dogs have eyes almost identical for amount of pigment with those of the albino negro, and in three cases out of four the observer thinks they have dark pupils, on the fourth occasion the red reflex is caught because the incidence of ordinary light is suitable. If four or five albino dogs are in a room together and they are then excited, any observer sees the reflex at all turns. My classification was, of course, a broad one but I think a serviceable one as it roughly graded the albino negro into two classes according to the intensity of ocular pigmentation, i.e. by manifest or non-manifest red reflex, observable by the traveller without apparatus. ED.]

Under my own Class (III) I shall consider cases of Xanthism as I understand that condition. Again I would refer to Sir H. Johnston's misleading remarks, "occasionally there are cases of positive Xanthism or a state of colouration similar in a much less degree to albinism—namely that wherein the colour of the skin and the iris of the eye is quite a light yellowish brown; this type is very much admired by the negroes." It is the last sentence which shows the incorrectness of the deduction, though this of course would not be appreciated by anyone who does not know the country.

The light coloured woman admired by natives has a yellow skin, a rather cold colour, with irides of a light brown, all the hair, however, is always black as in the average native. People of this colour are more common among certain tribes—the Achikunda, those of Senna on the Zambesi river, among the Yaos and the ruling families of Momberas Angoni—and I look upon this skin colour as a racial characteristic and not as a feature of Xanthism. Whether or not albinism is more commonly associated with such peoples I am unable to say, though Pearson thinks there is some reason to believe that blondism does exist side by side with albinism, occurring in the same districts and, it has been asserted, in the same stocks. This was first pointed out by Pritchard and has since been supported by Pearson, who quotes cases of men from Nyasaland observed by Turner in South Africa; the latter however remarks that these cases had "pubic hair brown," "in other cases the skin was a light rich red colour, wool on scalp a light yellow, the eyebrows and lashes reddish brown"; these cases I should immediately admit as cases of Xanthism but not those referred to by Sir H. Johnston, who does not mention hair colour and the skin colour of whose cases is yellow rather than reddish brown.

By Xanthism, then, I mean a condition characterised by a skin colour of reddish brown, red, or warm brown colour, scalp hair a golden or reddish brown, the same being true of the face and body hair, the irides being a light brown or hazel*.

Just as cases of imperfect albinism or partial albinism have to be recognised, so there are degrees in Xanthism, as in one of Turner's cases, but I look upon the distinctive points about the affection as the peculiar reddish "warm" colour of the skin, generally if not always associated with a similar colour of all or some of the hair; the yellow-skinned natives referred to above, though lighter in colour than many cases of true Xanthism, very seldom freckle as Xanthous natives do.

Dr Turner has also observed a number of natives with light hair "or down" on the temples, a fact which Pearson seems to think should be taken as significant as one of the first signs of a lighter pigmentation. With those downy hairs I am perfectly conversant but believe them to be merely an overgrowth of lanugo hairs. These fine downy hairs moreover are found in many natives elsewhere on the

* [The difference between Dr Stannus and myself appears to be that while I speak of a red or yellowish red skin, red, brown or even yellowish brown hair and brown to yellow irides as cases of Xanthism, he excludes anything beyond golden brown in the hair, or beyond hazel in the irides. Ed.]

body; they are always of the lanugo type and generally so small as to pass unnoticed but they will be seen to be of a lighter colour, golden to brown, and are quite distinct from the curled "woolly" hairs of the body skin.

There is another type of skin pigmentation for which a class has to be made. I refer to cases which with a light brown skin colour, not red and not yellow, and light hazel irides, have hair of a dirty yellow colour but with no red tinge in it. Some of these cases have photophobia and nystagmus pointing to deficient pigment in the eye. Typical cases form a well-marked group though I shall later show there are no absolute distinctions to be made between any of the groups or classes and that intermediate cases are met with all along the line. This last class is characterised by the fact that at birth the skin and hair are practically white but that slow darkening has occurred. The same may have been true of the irides but native observation upon which I have had to depend mostly in these cases has not been sufficiently good to remark this point.

These cases resemble the remarkable case of Dr Ascherson's referred to by Graves and quoted by Pearson, and are, I think, akin to those described by the same author as occurring in Papuans and elsewhere, in which the skin is darker than in the first form (ordinary typical albino) and in which nystagmus may or may not be present, where freckling is absent or at any rate not conspicuous, while the hair is tow coloured. Similar cases have been reported from Malay.

I have considered above albinism of various degrees but always affecting the whole of the skin, hair and eyes, that is to say cases of complete and incomplete albinism. It now remains to deal with the condition in which the affection is limited in extent, what is termed Partial Albinism. According to the extent of the albinotic characters this class is sub-divided by Pearson into Piebalds and Spotlings; the leucosis may be complete or incomplete.

It is therefore a difficult matter when considering cases to be sure under which category any particular one should be placed. Some doubt was entertained as to the existence of Piebalds until quite recently, when Seligmann's Papuan case, Gilbert Smith's English case and a family I have described from Nyasaland established the undoubted existence of Piebaldism. Persons showing a much less extensive area affected, often a single patch, have been conveniently called Spotlings and such are not uncommon in Nyasaland. It is to be noted that the area or areas affected tend to be the same in different cases. In Piebalds the belly and chest are involved and often associated with a flare on the scalp and "garter" or "stocking" markings. In Spotlings this arrangement and extent may be wanting. The various members of the Nyasaland family will be seen to present intermediate forms. This distinction into two groups is warranted by the fact that in a number of cases where the affection is inherited the type is preserved.

The resemblance of the Nyasaland Piebald family to Bishop Harman's family is worthy of note, and it has been suggested that such cases of human piebaldism

"are intensified representations of a light-bellied quadruped, that we have to deal with a case of palaeogenic inheritance," a subject associated with the name of Sir J. Hutchinson.

It will be found that I have set apart the Spotlings in which the penis only is affected as they form a special group owing to their great definition and owing to the little attention that has been paid to them.

I have pointed out, as will be seen later, that the pathognomic feature is the very light "pink" colour of the affected areas and their sharp margins.

My own working classification, therefore, is:

Complete albinos.	(I)	White skin, straw coloured hair, liquid blue iris with red reflex through pupil when examined with artificial light.
Spotted albinos.	(I*a*)	Cases as above showing spotty pigmentation of the skin.
Partial incomplete Albinism.	(II)	As above but the iris light yellow or hazel, photophobia and nystagmus not always present.
Xanthism.	(III)	Reddish brown hair and skin, light brown irides.
Incomplete Albinism.	(IV)	Skin light brown, not red; hair dirty light yellow, not brown; irides hazel.
Partial Albinism.	(V)	Piebalds.
	(VI)	Spotlings.
	(VII)	Spotling of penis.

II. *Illustrations of Anomalies of Pigmentation.*

I shall now give notes of cases and discuss the group to which each belongs. Some cases of leucoderma are then described after which the relation of leucoderma with albinism is discussed and the theories as to pathogeny of the conditions brought forward.

The cases of albinism so far recorded from Nyasaland are as follows:

A. 1. From Kayuni's, N. Nyasa, by Dr Davey (p. 145 *Monograph*).

2. Charlie* of Chikulamayembe, N. Nyasa, by Dr Davey (p. 145 *Monograph*).

3, 4, and 5. Cases mentioned by Mrs Young of Karonga, N. Nyasa (p. 145 *Monograph*).

* I have seen this case and would add to the description already given that the scalp hair of a light straw colour grows down over the forehead to the eyebrows. The whole of the back and limbs are covered with semicurved very light straw-coloured hairs. Irides light grey blue with a light orange-coloured pattern. Pupil black in daylight. Teeth irregular, ill-formed, and curious. The pedigree is given as Fig. 7 of Plate XXI, II 2 and II 4 were brothers, there are no other known albinotic members of the family.

B. Cases seen and reported by myself and included in the *Monograph on Albinism* (to which pages and Figures in Pedigree Appendix refer):

1. Girl aged 4½ years, daughter of Dingo, Chiromo; Fig. 426.
2. Boy aged 2½ years at Zomba; p. 148 ftn.
3. Chesiwandiri of Maumi, S. Nyasa; Fig. 430, Plate Y (77).
4. Ng'ombe, S. Nyasa; p. 147, Fig. 427, Plate Y (80).
5. Child of Mtila, S. Nyasa; Fig. 431, Plate Y (79).
6. Mbwerachaji } of Mvera, C. Angoniland; Fig. 428, Plate Z (84).
7. Kantaye }
8. Old man of Nkoma, C. Angoniland } Fig. 432.
9. Old woman „ „ }
10. Young woman of Nkoma, C. Angoniland; Plate Y (78).
11. Soto of Angoniland; Fig. 433.
12. Sikumbiri of Blantyre; Fig. 434.

In the families of these cases 6 other cases occurred making a total of 18.

13. The Piebald Family of Florence Bay; p. 250, Plates H (21), RR (147)—(150).

C. The following cases are now reported for the first time:

1. Alice.
2. Saiti.
3. John.
4. Pingo.
5. Chibwana.
6. Tom.
7. Ali.
8. Chikoya.
9. Nderemani.
10. Mateuta.
11. Child of Annie.
12. Moyichandi.
13. Sawali.

Case C 1. *Alice of Chikanji's Village, Dwangwa, Awemba Tribe.* Pedigree, Plate XXI, Fig. 11.

The father and brother, a boy aged 6 years, are of average colour, the mother is rather light-skinned, *café-au-lait.* No relatives are known to be albinotic.

The albino (Plate XVIII (25)) is a child aged 8 months, she has a pinkish tinge to a very white skin, no vestige of pigment visible. Hair as nearly white as possible, not woolly on head. Irides a slaty blue with orange pigment network round the pupils. Ophthalmoscopic examination impossible. Red reflex not present in ordinary daylight. Lateral nystagmus and photophobia marked. There are some blisters and sores on neck and ankles, the result of sunburn; on body and limbs fine white downy hairs present; a small umbilical hernia present.

This child, who presents complete albinism of the skin and hair, shows the peripupillary orange-coloured network, but no trace of brown pigment in the iris. At the present time, in the absence of any opportunity for making a microscopical examination of irides, showing this condition, I am a little doubtful how such cases should be classed. I think it is quite possible that this colour network is not due to granular pigment at all, but is caused by diffuse pigment such as is found in many specimens of red and golden hair, as will be mentioned later. This child is therefore provisionally placed in Class I.

Case C 2. *Saiti of Zomba. March,* 1910. See Pedigree, Plate XXI, Fig. 1.

The maternal grandmother is said to have been a light-skinned native (I 2).

The mother's skin colour is light brown; Bwanali (III 6) and William (III 5) are dark brown; the first four children are dead and other members of the family were said to be of average colour, a dark brown. Saiti (III 7 on Plate XXI), aged seven, is practically the same colour as the back of the hand (not sunburnt) of a fair European, there are some blisters on the shoulders and arms but no freckles; skin thickened in places. The body and limbs are covered with fine whitish yellow hairs. Hair of head a dirty straw colour; eyebrows and lashes thick and much curled. Eyes; lateral nystagmus present, day-blindness marked, irides bluish-grey, with a faint yellow pigment pattern; pupils black. With ophthalmoscopic mirror a red reflex shows through the pupil, but not through the iris. Fundus a light pink colour, possibly a little lighter than in the average European. Teeth very bad. Abdomen prominent, small umbilical hernia present.

This boy is a very characteristic case of Class I, but shows the orange colouration in iris.

The frequency with which albinos have body hair and also bad teeth will be mentioned later. The red reflex was here obtained and the fundus, though found to be even paler than in an average European, still contained enough pigment to prevent the choroidal vessels being seen.

Case C 3. *John of Mwandanas near Piupiu Hill, Zomba. January 6th,* 1911. *Mother and Father Anguru tribe.* Pedigree, Plate XXI, Fig. 5.

With the exception of the first child, which is said to have been white, all the other members of the family are known to have been averagely dark-skinned natives. An elder brother (III 3) was seen and found of average colour.

John (Plate XIX (28)), aged 6 years, a complete albino. Skin colour that of a fair-skinned European; in places harsh and dry, smooth, with cracking and some blisters from sunburn. On the lower part of the abdomen, especially on the outer surfaces in front and on adjacent surfaces of thighs, numerous warts are present, mostly small, only slightly raised, and rather flat-topped. Others are larger, as is one situated over each clavicle, there are also a few which are filiform in character. They appear brownish in colour. The body and limbs are covered

with light flaxen hairs semicurved, which, on microscopical examination, were found to contain no pigment granules. The hair on the head is very light flaxen colour, whisker areas covered with curved hairs. Eyelashes a golden brown colour, microscopically, no granular pigment in hairs*. Eyes: vision good in moderate light and pupils black, nystagmus present, red reflex present with artificial illumination. Irides, peripherally slaty-blue, round the pupil a light brown. The tongue has a bifid extremity. Teeth: two upper front incisors large, with serrated edges; all the front teeth above are spaced.

The child presents a fairly typical appearance of Class I save for the partial pigmentation of the irides, and on this account it must be considered as an intermediate between I and II. I am not sure whether the presence of the warts is of any significance; as far as I know, they have not been previously reported as specially associated with albinism. Note character of tongue and teeth.

Case C 4. *Pingo of Chitalu, Liwonde, seen Zomba* 18*th August*, 1910. Pedigree, Plate XXI, Fig. 2.

The parents, aunts and uncles of this case (II 3) and remoter members of the family are said to have been ordinarily dark-skinned natives. A cousin, a child of a maternal aunt, now dead, is stated to have been an albino. The eldest (II 1) of the family, of which Pingo is the second born, was albino, but is now dead; one other brother and three sisters normally black. Pingo is married to a normally dark native woman, who has had three children by him, all living and all dark.

Pingo (see Plate XIX (26) and (27)) is a man of 25 years of age. The skin of that part of the body covered by the loin-cloth is still very white, resembling the white skin of a European, and is soft and unaltered. The rest of the body shows changes in the skin of varying degree, the skin of legs being less affected than elsewhere; it is rough, harsh, scaly, cracked and creased with sunburns and superficial ulcerations; the skin is badly kept and dirty. There is hair all over the body and limbs, of a light straw colour; eyelashes, thick but ill-formed, are of a rather dark yellow colour.

Scattered over chest, abdomen, back, arms and neck, and also on the face are a number of areas from one third to one and a quarter inches in diameter, exhibiting a series of changes, giving the appearance of being of the nature of a pigmented atrophy; *pari passu* with the colouration, which commences as a light yellow colour, there is apparently an atrophy of skin substance, the final result being a black depressed spot, irregular in outline and with a brownish tinge at the edges, thrown into relief by the pinkish dirty white colour of the rest of the skin. Hair, a dirty straw colour, thick. Irides, a light opaque brown; lateral nystagmus present, but little photophobia. Pupils in daylight black. With artificial light, a red reflex is obtained, the fundus appearing a lightish red.

* The microscopical preparations of hairs in all cases referred to were made by Miss E. Y. Thomson, of the Biometric Laboratory, with the kind permission of Professor Karl Pearson.

When he smiles the subject has a retracted everted upper lip with fold of mucous membrane showing beneath it; the upper lip has a central linear depression instead of being pointed.

In reporting the case of Ng'ombe (B 4) it was pointed out that pigment spots hardly occurred apart from pitting and that the pitting might be the result of ulceration with scarring. In the present case, however, no history of such loss of substance could be elicited, yet a similar condition obtained. Both these cases are adults, whereas my other cases of spotted albinism are children in whom the pigmented areas are not depressed. Will these children develop depressed areas? I think they very possibly will. I believe that localised changes in the skin occur and cause the depressed areas, the pigmentation occurring before or at the same time, but whereas the pigmentation is visible in childhood the early results of depression are not seen. The irides of this man are a light brown, that is to say, more pigmented than in Ng'ombe, who only had an orange peri-pupillary ring. This case is included in Class II, though the iris colour makes it an intermediate type. A portion of skin including in its centre one of the pigmented spots was excised from the arm of this case and preserved*. Vertical sections were cut and examined microscopically stained and unstained and except for the complete absence of pigment granules the leucotic skin as a whole appeared in no way to depart from the normal. The several layers of the epidermis were not very thick, the dermal papillae and processes of epidermis between them being little developed but regular.

The structure of the skin at the site of the pigmented spot (freckle?) differed, however, very considerably. Here the dermal papillae are irregularly prolonged towards the surface so that the epidermal processes appear much longer but the rest of the epidermis thinner. The condition might be considered to resemble a wart which was "in" the skin and not "raised" above the surface.

Pigment granules were seen to occur in all the layers of the epidermis, most numerous in the cells of the downward processes of the epidermis, especially in the basal layer of these cells, which envelop the dermal papillae. They were seen to be more abundant in the peripheral parts of the cells and most densely packed at the deeper poles of the cells.

The granules were of a brown colour and where massed, appear as a homogeneous black mass.

In the subjacent dermis some cells were seen to contain pigment granules, they were few in number and the number of contained granules was small. Passing from the middle of the pigment patch where the aggregation of granules was greatest, they diminish in number as the periphery is reached. The diminution in the amount of pigment was seen to be gradual to one side of the section, the gradation taking place over several millimetres with some isolated

* See Plate XVII (21) and (22) for microphotographs of albinotic skin and "freckle."

masses of cells containing granules beyond. To the other side of the section, the transition is accomplished in 0·2 mm. This particular pigmented spot of skin was but very slightly depressed below the general skin surface, and though it is but a single observation I think the changes described would probably be found in all examples of the condition.

This is I believe the first time a "freckle" from a negro albino has been submitted to microscopical examination and it would be unwise to draw conclusions from this single observation.

Case C 5. *Chibwana of Chikala. July*, 1910. Pedigree, Plate XXI, Fig. 4.

Mother and father and two brothers and a sister all normally dark-skinned. The maternal great-grandmother had said there was an albino in the family ancestry.

Chibwana (see Plate XVIII (24)), a boy aged 4½ years (1910), has a dry cracked skin the same colour as a fair European; pigmented patches are gradually appearing on the face, also but less marked on chest and back and less still on the limbs. These patches are irregular in outline, black or dark brown in the centre, and a lighter brown at the periphery, but they are not depressed. Hair on head reaches to eyebrows, there is hair also on the cheeks, back, arms and legs, with little on chest, semicurved and white; on microscopical examination, it is found to be devoid of granular pigment. Eyelashes long and curled, of slightly yellower tint than hair on scalp. Irides, olive green with buff yellow pigment ring round periphery; pupil, not quite circular in outline, appears black in daylight. Lateral nystagmus present. On ophthalmoscopic examination a red reflex is obtained through the pupil, none through iris; fundus pink as in European.

I think in this case we see an early stage of the condition found in Pingo, which may progress until a condition similar to Ng'ombe is reached.

Case C 6. *Tom of Chifira's Village, Bandawe, W. Nyasa.* Pedigree, Plate XXI, Fig. 8.

The mother and father, former dead, were both of average colour. No history of albinism in the more remote ancestry. The first three children were albinos but were killed at birth according to custom among the Atonga. The fourth child was allowed to live owing to more civilised ideas of the chief, but died at the age of 15 years.

Tom, the last born, a boy aged 14 years (1909) is mentioned in the *Monograph* and a photograph by Dr Robertson there reproduced (Plate PP (142)), but the history of the case is not given*. The skin of non-exposed parts is a pinkish white colour, elsewhere it shows sun-tanning and also a considerable degree of spotty pigmentation, the colour being not a brown to black, as seen in other cases, but a golden yellow like ordinary freckling in a European. Irides a light hazel

* [Given as Fig. 648 in Part IV of the *Monograph*. Dr Robertson states that there were two *normal* siblings and does not mention the dead albinos. ED.]

brown. Photophobia and lateral nystagmus present. Dull red reflex present with artificial light. Vision very fair. No hair on body. Hair very white as opposed to the usual light straw colour; microscopical examination showed it to be without pigment.

The lad, though one of the lightest haired cases I have seen, had hazel irides, though, be it noted, as nystagmus and photophobia were marked, he would be placed in Class II, but owing to his spots, he is considered in Class I *a*. The spots of pigmentation present, however, do not approach in colour those on the younger boy Chibwana. Tom lived near a mission station, and I think may have worn more coverings than the other cases, who wore only a loin-cloth. This series of five albinotic siblings, all the children born, is a remarkable example of albinism in a family.

Case C 7. *Ali of Mwaimba, near Mvera, S. Nyasa; Yao; male, aged* 16 *years.*

Three elder brothers, one younger, and one younger sister, mother and father all very dark. No more remote members of the family known to have been albinotic. The skin colour of the subject is a light "warm" *café-au-lait*. He is covered with fine golden hairs all over the body; hair of scalp, face, axillae and pubes a dirty straw colour. Irides a light reddish brown. Nystagmus present. Pupils black. Using an ophthalmoscope in a dark chamber, a red glow through pupil is obtained, but none through the iris. The optic papilla appears normal. The fundus reflects a red glow, a little lighter than that of a European; choroidal pigment is almost completely absent, allowing the choroidal vascular network to be completely visible, the small amount of pigment being collected into small deposits lying between the vessels.

The salient features of this case are a skin and eye colour which would cause me to consider it one of Xanthism, the hair also is rather dark for Classes I or II, but, on the other hand, the fundus is found to have less pigment in it than most other cases. He must therefore be considered to be an intermediate form presenting affinities with Class II and Class III. He has hairs all over the body, which I look upon as a condition very commonly associated with albinism.

This case I consider an important one in linking up the several types.

Case C 8. *Chikoya of Mulowi, W. Nyasa. November*, 1909. Pedigree, Plate XXI, Fig. 6.

Chikoya, a man of 25 years of age, is stated to have been, as a child, quite white, but has gradually darkened to present colour, of dark sunburn in a European; skin fine, not thickened nor cracked. Fine golden hairs are present on the arms, legs and shoulders; there is a light yellow golden moustache and beard; the hair of the scalp is a dark brown colour, as is also the pubic hair, but on microscopical examination it is found to contain only diffuse pigment and no granules. Hair said not to have darkened with age. Irides a light hazel; no photophobia; no nystagmus, vision good.

In this man we see a case to be placed in Class IV, a group characterised by light brown skin colour (not red), in adult life, with nearly always a history of darkening with age; the irides are hazel, the hair, though it is a dark brown colour, contains no pigment granules.

Case C 9. *Nderemani of Namalwere Village, Fort Maguire.*

This man, aged 25 years, was seen in Zomba in 1911 when returning from work on the South African mines.

Skin a rich "warm" brown colour; hair a rich red brown hue; axillary hair a dark brown; there are a few golden coloured hairs on the body and limbs. Irides, dark hazel; no nystagmus; vision good. There is a small umbilical hernia present. He says he has darkened with age and more rapidly since going to the mines than before.

This is a typical case of Xanthism, Class III. The hair, on microscopical examination, was found to contain few pigment granules, but a considerable amount of diffused pigment.

Case C 10. *Mateuta of Chiri, W. Nyasa.*

Father of average colour. Mother states that she used to be "white" when a child; at the present time her skin tint is a light brown; irides hazel; hair black.

Mateuta, a child aged 2 years; skin colour a very light brown, face of lighter tint than body; irides greenish hazel, no nystagmus; hair light brown yellow with red glint in it; eyelashes and brows of a lighter shade; no hair on body. As an infant, is said to have been nearly "white." Vision apparently good. Mother and child constitute, I think, a short series, showing a progressive pigmentation, of value to the general subject.

Their histories show them to have possessed at birth a white, or almost white skin, which has become pigmented with age; the child's skin has not yet reached the degree of pigmentation of the mother's. The child's hair is a light brownish yellow, which is becoming darker; whether it will actually become black remains to be seen, but I expect it will. The same is true of the irides. The mother's are hazel, the child's are greenish hazel, strongly suggesting that increase of pigmentation is in process of taking place.

Case C 11. *The child of Annie and Annausu of Nkumbira, Nkata Bay.* Pedigree, Plate XXI, Fig. 12.

All relatives dark; no other cases of albinism in family. The child (II 12) aged 8 years, is stated when born to have been almost white and to have darkened since; the same is said to be true of the hair. The face is a very light sallow earthy colour with dark freckles; skin of body a warmer tint of brown. Hair of scalp dark brown. A few fine downy hairs are seen on the body and limbs. Irides hazel; no nystagmus; vision good.

This child, aged 8 years, can, I think, be taken with Mateuta and his mother and might be placed in the series as intermediate between the mother and her child. Together they seem to illustrate simply a delay in normal pigmentation, a phenomenon to which I do not think attention has been drawn, but one which must be taken into consideration when any attempt is made to theorise on the cause of albinism.

Case C 12. *Moyichandi of Sangano, Blantyre, Yao.* Pedigree, Plate XXI, Fig. 3.

Moyichandi, aged 18 years (II 5), is the brother of a case (B 12) Sikumbiri (II 6) previously reported in the *Monograph*, Fig. 434.

The skin is a light but "warm" reddish *café-au-lait* colour distinct from any normal native skin colour; irides hazel; no nystagmus. Hair light brown in colour, which on microscopical examination was found to contain fairly abundant granular pigment and a considerable amount of red brown diffuse pigment.

Sikumbiri, a year younger than his brother, has a lighter tint of skin, not so red; the irides are light hazel and nystagmus is present; hair dirty light straw colour. Both have hair on body and limbs of a yellow colour. In these two brothers we see an excellent example of the connection between two grades of deficient pigmentation; the elder I should class immediately as a case of Xanthism, whereas his younger brother must be placed as an intermediate between Classes II and IV. See Plate XVIII, Fig. 23.

Case C 13. *Sawali of Ntiya Village, Mlumbi, Zomba; Yao,* 1911. Pedigree, Plate XXI, Fig. 9.

Sawali, II 1 (for photograph see Plate XII, 1 and 2) and his younger brother, II 2, aged 13 and 5 years respectively, of whom the elder one only was seen, are said to resemble one another. Sawali seen in January 1911; hair of scalp from light yellow to brown, fairer on neck and at the edges of the hairy scalp; eyebrows and lashes black, no hair on body, pubic hair black; no albinotic characters in the skin, i.e. the skin is of a slightly lighter tint than the average native, but well within the limits of normal. Irides medium brown; no nystagmus; vision good. Teeth, all the incisors are serrated thus: ; they have the appearance of having ill-developed enamel.

Seen again two months later. He had in the meantime cut his hair very short, almost shaved, and allowed it then to grow again; the soft less-curled hair on the temple is a mouse-brown colour, the newly grown, tightly curled wool of the scalp is of a yellow colour, becoming brown near the roots; scalp colour is the same as the skin. He states that he was born with a white skin which has darkened since.

Individual hairs were found to vary in colour; some very light golden hairs were found microscopically to contain a yellow diffused pigment with very fine

granules in fairly large numbers; brown hairs contained brown diffused pigment and abundant granules; some light hairs contained comparatively few granules, fine and widely scattered. There are some spots of pigment-like freckles of dead black colour, a few on neck, chest and back. On ophthalmoscopical examination a slight dark grey red reflex is obtained through the pupil; the fundus is a dull red, rather lighter than in average native.

Cases of partial albinism in which the hair only is involved but completely must be of rare occurrence, and I know of no case among African natives; such a striking figure, if seen, would surely have been recorded.

Note should be taken of the character of the teeth and the presence of body hair. This case should be considered together with the last cases above mentioned.

III. *Piebalds and Spotlings.*

With the exception of the Florence Bay family referred to earlier in this paper no other cases of Piebaldism have been seen.

The following cases are examples of spotlings that I have come across in Nyasaland. In the first group mention is made of white tufts of hair: in the second, spotlings of the skin are described.

(A) Several cases of natives presenting congenital white tufts of hair have been seen; they resemble each other almost exactly in that the canities occurred in the form of a median-placed flare on the anterior half of the scalp more or less triangular in arrangement, base in front. There were generally also a few white hairs scattered over the rest of the topmost portion of the scalp.

One such case also presented right and left helical fistulae, a congenital anomaly of no significance in this country, as it occurs in about 4% of the population.

Salule, of Chitanji Village, Chiradzula, showed two small tufts of white hairs, one placed in the median line, the other a little to the right and behind it, at the summit of the scalp; the scalp beneath them was a little lighter in colour than the surrounding. This man states that he was born like this and that one of his brothers, but no other member of the family, is similarly affected. The white hairs submitted to microscopical examination were found to be devoid of pigment.

G., the wife of a private in the King's African Rifles, aged 25, was seen to have white hairs scattered over the scalp which were said to have been present since birth; she presented no other albinotic characters.

Chitesima was another example of this condition. Microscopical examination showed the white hairs to be devoid of pigment, granular or otherwise.

H., a girl, aged 6 years (1909), from a village on the Lake shore in West Nyasa, presented a curious and interesting condition exemplifying partially

deficient pigmentation. The affected areas were the right side of the upper part of the face, two small patches on the same side of the neck and a patchy condition of the fingers. (See Plate XIII, Fig. 5.)

The area on the face was sharply limited along the mid-line of the nose and forehead. The two patches on the neck were at the anterior margin of the trapezius muscle over the mid-point of the clavicle. The mottled condition of the fingers rather resembled that seen in Ziemann's leucoderma.

The general skin colour was that of cake chocolate. The affected areas were the colour of bruised chocolate. In addition to the affection of the skin, a segment of the iris about one-sixth of the total iris in extent, with the base directed towards the right side, was of a light hazel colour, the remaining five-sixths being a dark brown, the same as the iris of the other side. The hairs of the scalp, eyebrows and eyelashes were normally black. The condition was noticed at birth, according to the mother's statement, and had not altered. The mother, father and brother of the subject were all normal, and no members of the family were known to have presented any pigmentary anomaly.

I., female, aged 5 (1909). Seen at Kondowe; she presented congenital anomalies of pigmentation in that there was absence of full colouration of the skin; the back of the right hand, with the inner three fingers, the palm, and the back of the right arm, the abdomen, groin, thigh and leg of the same side were the seat of patchy deficiencies of colour, with spots quite white or pinkish white to various shades of brown, resembling somewhat the condition seen in leprosy, or the non-leprous leucodermic affection of the skin of the hands described by Ziemann. The condition was stated to be congenital and not to have altered. No other members of the family were affected.

Daus, of Chimwai village, Dwangwa River, male, aged 11 years (1909). An area of skin on the cheek, as indicated in Fig. 6, Plate XIII, is of pinkish white colour resembling that of an albino; the area is smooth and on the same plane as the surrounding dark skin. The demarcation is abrupt, with no increase in pigmentation of the skin in the neighbourhood. Over the albinotic patch and also more abundantly on the surrounding skin are distributed fine white short curved hairs, no other hair being present on the cheeks. A few white hairs are seen on the same side of the upper lip, and the middle portion of the eyelashes on the upper lid of the same side are white.

There is an area of skin just in front of the tragus of a lighter hue than the rest of the skin of the face, which is a rather dark brown black colour. Irides dark brown. History states that these anomalies of pigmentation were present at birth. They have enlarged with growth, but there has been no relative increase in size. No other members of the family known to be albinotic.

The girl "H." presents a condition of extraordinary interest. In the first place, I can put on record a case of congenital incomplete spotling albinism, that

is to say, a case with small areas of skin, congenitally deficient in pigmentation, but not completely albinotic. Secondly, the case demonstrates, I believe, a previously unrecorded condition, a partial and incomplete albinism of the iris; it is noteworthy also that the condition only affects one side, in fact the area on the face is strictly limited to the one side by the mid-line of the nose. This case will be mentioned again later.

In speaking of the other two cases I am not quite so sure of my ground.

The girl "I." presents no definite pink area of skin, but a condition resembling very much that described as Ziemann's leucoderma. It is said to have been present at birth, and the similar condition of fingers in the girl "H." supports the probability of this statement being true. The history that the condition is not changing is against leucoderma and therefore, on the whole, I am inclined to include it as a case of spotting.

(B) The special group of partial albinos characterised by an affection of the glans penis must now be considered.

My attention having been drawn to the point, the condition was then sought for among a number of adult men aged from 20—50, and including circumcised and uncircumcised, those with a partly retracted prepuce and those with a long covering. More or less complete circumcision is practised among the Mohammedan Yaos, but not among other tribes.

At the outset one must recognise that, just as in Europeans so in natives of Africa, there is very considerable variation in colour of the glans penis and inner surface of the prepuce, colour conditions which are fairly comparable to those of the mucous membranes. Just as in Europeans, variations from a delicate pink to the colour of uncooked lean bacon, from almost white to a purple red, occur; a similar variability is seen in uncircumcised natives, but always in the darker hues, that is, the skin in this situation always contains some pigment.

Dr Stachan, quoted by Pearson, states that the glans penis beneath a phimosed prepuce is always red; I am not quite sure whether he wishes to infer that the skin is devoid of pigment or not, but certainly the latter condition is the truth.

In the circumcised, the glans is practically always of the same hue as the rest of the penis and scrotum, i.e. a darker tint than the general colouring of the body.

In the uncircumcised, as a rule, according to the extent of the natural uncovering of the glans so is the degree of pigmentation.

The portion of glans normally uncovered by a naturally partially retracted prepuce is often darkly pigmented, shading off to red as the corona is reached; sometimes the general colour is a dark lean bacon-red, it may be with a purplish hue; in others, the general colour of the glans is an opaque leaden white. In

all these cases, however, all variations in colouration shade into one another, and it is evident pigment is present.

Those cases which I have considered as spotlings show areas of various extent, always of a "pink" colour, with sharply defined margins, this being the test of a departure from the normal, which I consider includes the variations in colour above mentioned.

The following is an analysis of nearly 400 adult males, between the ages of 20—50 years, being prisoners and soldiers, and therefore they can be considered as taken at random from various tribes.

379 *Adult males examined with reference to colour of glans penis and prepuce.*

(A) 122 Circumcised: All have completely black glans penis except two (*a* and *b*).

(*a*) Some spotty pinkish colour present at the seat of the operation cicatrix. (N.B. the circumcision was performed when subject was adult.)

(*b*) Chambveka, the general colour of the glans is a dark brown, but there is a light brown spot on the dorsum near the meatus.

(B) 259 Uncircumcised:

(1) Inner surface of prepuce and the whole of the glans penis dark brown or black . . . . . 45.

(2) There is a gradation of colour from the corona to the meatus and corresponding part of the inner surface of the prepuce from blue red, leaden or yellowish white to dark brown or black . . . . . 100.

(3) Glans and inner surface of prepuce of a uniform colour, from a leaden white to a bacon-red . . . . . 75.

(4) Glans and inner surface of prepuce of about the same colour as in a fair European, but at the free edge of the prepuce shading off into dark brown or black of the general skin colour . . . . . 20.

(5) As in (4), except that the lips of the meatus were dark brown 3.

In another case there was some deeper pigmentation about the frenum shading off into the surrounding colour; the skin colour was a dirty yellow brown, rather like that of a half-caste, with some freckling; hair black; irides dark brown . . . . . 1.

(6) Spotlings . . . . . 15.

From the above it will at once be seen that among the circumcised one may say no spotlings were found; case (*a*) had some alteration in the neighbourhood of a scar and is of no import; (*b*) had a condition which may be called leucoderma, or may be a congenital condition, and be called albinotic, but no history was forthcoming.

Colour variations among the uncircumcised, (1—5) came within the limits of normal variation as above described. The single case mentioned in (5) I look upon as really one of the intermediate cases towards albinism, a view strongly supported by the freckling.

To deal with cases under (6) in detail:

(*a*) Lijuni, aged 30, glans and inner surface of prepuce a very bright pink (considerably lighter in colour than in an uncircumcised European), bounded by a sharp line of demarcation at the junction of the inner and outer surface of the prepuce. There are a few white hairs in the mid-line of the beard and at the outer corners of the moustaches, but no other albinotic characters. See Plate XIV, Fig. 8.

(*b*) Erya, an Angoni, as in (*a*) but with an area of dark brown, involving the lips of the meatus, though covered by prepuce, thus differing from cases mentioned above (5).

(*c*) Matesi, an Atonga (see Plate XV, Fig. 11).

(*d*) Jim, ground colour of preputial-glans-skin of a reddish grey, albinotic area shown in Plate XV, Fig. 12. Skin colour a dark chocolate; irides dark brown; on the front of the abdomen there is a spotty condition, light and dark brown; there are a few freckles, one each on the right side of the abdomen, left chest and back.

(*e*) Chizizu, Yao (see Plate XV, Fig. 13), nothing else to remark.

(*f*) Lief. Dark brown skin and irides (see Plate XV, Fig. 14).

(*g*) Chiwia. Besides the larger patches of albinotic skin on the glans, there is a spotty pigmentary change about the frenum (see Plate XVI, Fig. 15). The skin and irides were a dark brown colour, and there were some scattered grey hairs on the scalp. Man, aged 30 years.

(*h*) Chivia, Angoni, skin and irides dark brown (see Plate XVI, Fig. 16).

(*i*) Naamon (see Plate XVI, Fig. 17).

(*j*) Yohani. There is a patchy light and dark brown pigmentary change in the neighbourhood of the frenum.

(*k*) Magombo. Red pink ground colour of glans, etc. with leaden blue spot, as shown in Plate XVI, Fig. 18, skin colour a dark chocolate.

(*l*) Asani like (*k*), only spot is brown in colour; scrotum and penis black, skin colour light brown with large black freckles, one on each leg, and some on body and face.

(*m*) Mwenengwi. Tightly phimosed, but some spotty pink areas can be seen ju... on the inner surface of the foreskin.

A further case has since been seen. Binali, 1st K. A. Rifles, Zomba, 1912 (see Plate XIV, Fig. 9).

Lijuni [(*a*) above] was circumcised by me on 5th April 1911. Fourteen months later he was again seen. Examination revealed a circular patch of pigmentation dark brown in colour involving the lips of the meatus and a small area round them, three-eighths of an inch in circumference; the remainder of the glans was of a light pink colour, totally devoid of pigment as at the time of circumcision. The prepuce was carefully preserved and transverse sections prepared and mounted unstained and stained with haematoxylin and eosin and by Van Gieson's method for microscopical examination. I may say at once that, with the exception of the deficiency of pigment granules, the whole structure of the albinotic areas of the skin appears normal. In the normally pigmented part of the prepuce the basal cells of the Malpighian layer are the most deeply pigmented, some of them being so full of dark brown granules as to appear almost black and homogeneous; this is most marked in the cells at the end of the deep processes of epithelium dipping down into the dermis and also in the cells lining the lower parts of the sides of these processes. Those cells less deeply placed are less pigmented, but all the cells, even the most superficial ones, of the stratum corneum contain some granules. The granules tend to be arranged round the periphery of the cells, especially at the distal end of the cells, giving a very characteristic appearance. In the subjacent dermis a few cells containing pigment granules are seen, small in number and not very heavily pigmented. The transition from the normal pigmentation to skin absolutely devoid of pigment is seen to occur in from 1 to 2 millimetres, that is to say, it is not absolutely sudden but the gradation is rapid. The diminution in the number of granules is practically proportional in all layers of the epidermis; in the dermis the loss appears possibly to be absolute before the same change is complete in the superjacent epidermis, and the cells lining the sides of the deep epidermal processes retain a greater number of granules than the cells at the more superficial and deeper parts: see Plate XVII (19) and (20).

Prolonged beyond the last cells containing granular pigment a band of yellowish brown diffuse colour is visible affecting a layer of cells two or three cells thick at the junction of the stratum corneum and stratum granulosum.

IV. *Notes on Anomalies of Hair Pigmentation.*

Samples of hair were examined with results as follows:

Simbeleta and *Nederi*, a type of rather coarse hair, which is not very curly, recognised by the natives as turning white early in life. Microscopically white hairs were devoid of all pigment, a few brown hairs showed brown diffuse pigment, with densely packed granules, the black hairs being normally black and completely packed with black granules.

Mwana Ngala. Aged 2½ years, stated to have had yaws, and in consequence of this illness the hair at the sides of the head and temples is brownish in

colour; microscopically there was a diffuse brown pigmentation and granular pigment was fairly abundant.

Another child showed the same changes under similar conditions.

Old female inmate of the Central Prison of an age when grey hairs have usually appeared; she was noticed, however, to have some brownish hairs, and others of a bright golden colour; the black and brown hairs were found to be tightly packed with black granular pigment—the golden hairs contained light yellow diffused pigment, but no granules.

Kause. An old female lunatic, presented the same hair characteristics, macroscopic and microscopic.

Three men were noticed with a certain number of red hairs in the moustache, comparable to the hairs in the moustache of a "red haired" European.

Yotam. Scalp hair black; skin a lightish brown, is said to have darkened with age; irides a dark hazel. Microscopically the red hairs contained a certain number of fine pigment granules, but also bright red diffuse pigment, black hairs absolute black, with granular pigment; some of the hairs were partially red and partially black, each part showing the corresponding condition mentioned above.

Pamandhe. Brown moustache hairs showed diffuse brown pigment and fairly plentiful black granules; black hairs and some particoloured hairs as in case above.

Chamveka. Light brown hairs were devoid of pigment granules, there were some particoloured hairs, which, with black hairs, answered to the description above.

Bandsman, 1st K. A. R. Hairs from dermoid cyst of forehead. Hairs spindle-shaped, tapering at each end; brown diffuse and granular pigment present, but not equal to full pigmentation.

V. *Case of Leucoderma.*

I now describe a case which clinically is one of leucoderma. It is the only case showing leucodermic areas of any extent that I have met with, from which I think I may infer with reason that leucoderma is rare among these natives save in its minor manifestations.

This case corresponds very well with a text-book description of the disease—a symmetrical and progressive condition associated with hyperpigmentation. Points of interest are that the patient is sure the hyperpigmentation has occurred on sites previously depigmented. The hairs on affected parts of the skin which are naturally hairy are black. Black hairs are also seen to occur on leucotic areas on non-hairy portions of the skin.

Ouda, of Chechiwere's, male, aet. 15 years, Zomba, November 14th, 1910. Disease started 3 years ago; he was seen at that time by my native Hospital Assistant who vouches for this date. He has never had yaws. The disease

commenced as a very small patch on the right shoulder which has never spread. Now spots are seen on the body, face and limbs (Plate XII, Fig. 3).

He states that a patch appears very quickly, in a few days reaching its maximum size and that the extremities are the last to become involved. At the present time the middle two-thirds of the red margin of the lower lip are affected, there is a patch on the right side of the filtrum of the upper lip, some small areas over the left shoulder, three patches the size of a half-penny over the upper part of sternum, a few points over the chest and abdomen in front and on back; the arms from the elbows downwards are the seat of large patches; the wrists, thumbs, dorsum and palm of hands and fingers also show patchy depigmentation; patches on the left knee, the dorsum of the feet and toes, and over the ankles are also present.

These affected areas are of a pink colour as of a fair European skin; they are in some places a little crusted.

There is a lack of signs of slow depigmentation, that is, areas of all shades of dark brown to pink are absent. In association with some pink areas there is a surrounding hyperpigmentation; these the boy states were previously depigmented and pink. This phenomenon was well seen on the arms, the leucotic areas presenting black hairs as on unaffected skin. Affected areas over the manubrium sterni, though there is no hair on the surrounding normal skin, present hairs which are black. No one else in the family affected.

Under the name of "Melung" (Beta), Ziemann has described in the *Archiv für Dermatologie und Syphilis*, Bd. LXXIV. S. 163—170, Wien und Leipzig, 1905, a skin disease among negroes on the West Coast of Africa "characterised by the appearance of round, oval or irregular shaped patches of a bright yellow red colour on the skin of the extensor and flexor surfaces of the hands and feet." Here in Nyasaland I have seen a number of cases which correspond more or less with the descriptions given by Ziemann, but there are several points of difference, and I am inclined to think that that observer has made too hard and fast limits for the type of leucoderma which he has described. He says, "The predominant colour of the affected areas is of a whitish tinge and the general aspect may be compared to that of extensive superficial burns which have healed without the formation of granulation tissue. The disease begins at the age of from 10—15 years; its course is symmetrical, either attacking the hands first and then the feet or the feet first and the hands afterwards, or both at the same time. The progress of the disease is extremely chronic." He further notes that never more than four-fifths of the surface of the hands or feet are affected with pigment atrophy. The flexor surfaces are more extensively involved than the extensor, the pigment atrophy is practically confined to the hands and feet, only further slight extensions occur after 10—20 years and there is gradual loss of pigment in the hairs situated in affected regions. Sensibility to touch, temperature, and pain and muscle sense are unimpaired; the sweat glands are normal;

the electrical reactions of the affected limbs are normal and there is no evidence of disease of the nervous, blood or excretory systems.

As far as I am aware no mention has been made of the disease occurring elsewhere than among West African negroes, I therefore give some details of a few cases met with by myself.

Chisfufu. Male, aged about 36. The headman of a village near Zomba. Subject states that the disease commenced on the left side of the chest when he was 6 years of age, then both hands and arms were affected followed immediately by the legs, and it has been slowly progressive till the present time. When seen there was a spotty hyperpigmentation on the front of the chest (see Plate XX, Fig. 29) only two areas being actually of a pink hue, the same condition is seen on the back; the changes on the hands and feet are typical. The depigmentation seems to have occurred in circular areas so that on fusion the margin assumes a scalloped form.

X. Female, aged 50. States that her affection only commenced 2 years ago. On examination the left hand and wrist are found to present the typical features of the disease, and though of only 2 years' duration it is as marked as in cases of 20 years' standing. On the palm of the right hand there are some spots $\frac{1}{8}$" in diameter of slight hyperpigmentation, signs of the commencement of the disease in this extremity.

Binti Masua. Female, aged 30, of Mponda, wife of Mwini Dowa, private 1st King's African Rifles.

She states that she had yaws when aged 8 and that the leucoderma appeared at that time, and has remained of about the same extent since childhood. On examination there are seen some black areas on the arms, apparently the hyperpigmented scars of old yaws. She has a Dupuytren's contracture affecting both little fingers, the first interphalangeal joints of both hands are thickened, and the fingers show a slight degree of ulnar deflection. The affection is less advanced in the left hand than the right. In the former the depigmentation only affects the palm, while on the right side, the dorsum and fingers are also involved. Hyperpigmentation is present as a band round the wrist, along either border of each hand across the bases of the phalanges and on the back of the first fingers and sides of the middle fingers.

Licheta. Male, aged 50, inmate of the Central Prison, Zomba, an Angoni of Dedza.

The disease is said to have commenced at the age of 17 on the palmar surfaces of the wrists, since when it has very slowly spread till the present time.

The affected areas include both surfaces of the hands and wrists, and extends two inches on to the forearm; the depigmentation is patchy in character; where the process has been most intense the skin is of a yellowish pink colour. Circular areas are seen showing all grades of depigmentation as evidenced by the different

shades of brown present. Round the areas in which the change has taken place there is hyperpigmentation more or less marked, in some areas the skin being absolutely black. There is a worm-eaten appearance on the palms of the hands which the man states is the result of yaws in boyhood. There is also compound ganglion affecting both wrists. The photograph (Plate XIV, Fig. 10) illustrates rather poorly these features.

Mundana. Male, aged 40, of Chikumbo, Mlanje, Makua.

Patient states that the affection of his hands and feet was present at birth, and has not altered since. This I think is very doubtful and probably one may infer that the disease began in very early childhood, and has not progressed of late years. He says he has not suffered from yaws. Both hands and feet are affected, the former to a small degree and the feet still less, so that it is hardly noticeable in the latter.

There are only two or three small areas actually pink, for the most part the colouration is patchy and of various shades of brown to orange. The process has involved the hands and fingers, the wristband area and the dorsum of the foot and toes on both sides.

There is a hyperkeratosis of the palms of the hands and of the skin of the extensor surfaces of the interphalangeal joints. The palms of the hands also present a worm-eaten appearance with the formation of little pits. There is likewise heaping-up of epidermis with cracking at the flexures on the palms. The hairs on the extensor surfaces of the fingers have fallen out, leaving little pits.

Y. Male, aged 40. A Swahili from Zanzibar, Range Capitao, Zomba. The hands only are involved, but in a perfectly typical way. The disease is stated to have commenced when the subject was a small boy.

Other cases have been seen but of them no notes have been kept. In discussing the relation of these cases to ordinary leucoderma it must be remembered that natives are seen with a similar patchy speckled depigmentation process affecting the skin of other parts than the hands and feet. Thus I have seen a condition along the middle line of the back or in the middle of the chest on several occasions. In the case of a girl I., aged 10 years, mentioned above, it was associated with similar speckled condition of the fingers, and was said to have been present at birth. Chisfufu, as will be seen by a glance at the sketch on Plate XX, not only had a typical affection of the hands and feet but the process also involved the trunk, all four limbs and the lips.

While it is true that there is a large number of cases of an "imperfect" leucoderma corresponding more or less to the description given by Ziemann, I find that there are many others in which the process is wider in its distribution and which are therefore connecting links between the type described by Ziemann and ordinary leucoderma. Even in such cases of long standing the areas involved are of small extent, and it is but seldom that one would see a portion of skin of

any size reduced to the pink colour such as is seen in ordinary cases of leucoderma in natives.

It is however difficult to see where to draw limits around any particular type, though I must agree with Ziemann in setting apart the hand and foot type as a fairly definite variety. I agree with him in thinking that the disease does often start during youth, but I am not convinced that it always does so. Again it is nearly always symmetrical after it has been existent for some time, but not always so at the beginning. I believe that in most cases the hands are affected before the feet, and though in the majority of cases the progress is very slow, yet in some it may run a more rapid course for a time, and then become stationary.

I have certainly never seen more than four-fifths of the hands or feet affected. The flexor surfaces are more extensively involved than the extensor, but the change is by no means so commonly limited to the hands and feet as Ziemann makes out. I would say that it is more usual for some two or three inches of the fore-arm to be involved as well. I should be inclined to lay more stress on the character of the colour changes. Practically in all my cases there was hyper-pigmentation to be seen in areas of skin adjoining those in which loss of colour had taken place. This was generally most marked as a black band around the wrist, but was seen elsewhere.

The loss of pigment as above mentioned would appear to take place at a number of points more or less at the same or at different times, so that round areas are produced showing varying degrees of loss of colour which may coalesce with the formation of larger areas with scalloped margins. Often in the middle of such a depigmented area, one that may have been reduced to whitish-pink or yellowish orange colour, small spots of more deeply pigmented skin may be seen to remain.

Ziemann has compared the appearance to the result of extensive superficial burns which have healed without the formation of granulation tissue. Such a description I do not consider good, as under those circumstances the skin is essentially pink and never of the orange yellow or yellow white colour characteristic of the affection under consideration. Again, the laying down of pigment after burns occurs at points partly separated from one another, which appear very dark indeed, and do not resemble the darkly pigmented patches seen in this disease.

Attention might again be drawn to the fact that the history of yaws was obtained in several cases and a few show evidence of lesions almost certainly the result of framboesia, I refer to the pitted appearance of the hand and hyperkeratosis. The loss of the hair from the digits in one case should also be noted as possible evidence of a trophic element in the etiology of the affection.

Below are short notes of cases of melanodermia of congenital origin as far as their histories could be elicited.

Female, aged 17, Zomba, 1910. An area of absolute black skin is seen on the right side of the neck extending over the clavicle. No other affection of pigmentation noted.

Bimba, male, adult, Zomba, 1910. Patch of black skin on the dorsum of the left foot, over the heads of the first and second metatarsal bones.

Talo, adult, male, 1st K. A. Rifles, Zomba, 1911. A black patch of skin under the right nipple.

Mainana, adult, male. Below right axilla there is an area of skin 4—5 inches square in extent of a dead black colour.

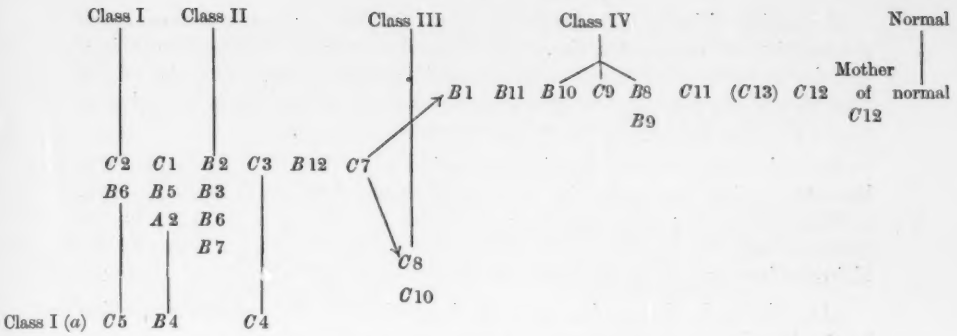
Conclusions.

The cases I have cited go to illustrate the following facts:

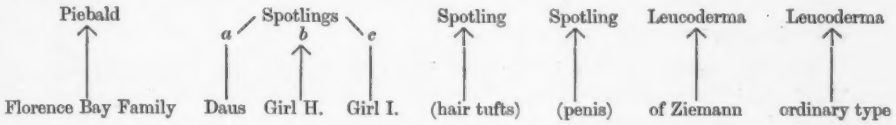
1. Albinism is common among the natives of Nyasaland.
2. It is a family affection and often directly hereditary.
3. Varying grades of albinism are met with in the same family.
4. Almost every degree of albinism is met with.
5. The degree may vary with age.
6. A secondary laying down of pigment in the albinotic skin in spots is a not uncommon feature.
7. Albinism is very generally associated with an unusual development of the lanugo hairs and less commonly with mal-development of the teeth.
8. Piebalds are comparatively rare.
9. Spotlings are less rare.
10. There is a very definite class in which the spotling condition affects the penis only.
11. Widely distributed leucoderma is uncommon.
12. A localised form resembling that described by Ziemann is common, but intermediate cases between this form and a more generalised form are seen.
13. Some congenital cases of spotlings resemble exactly some cases of leucoderma.

The grades of albinism in their relation to one another may be diagrammatically represented; this arrangement has however no pretence to mathematical precision.

In the same way the relations of the various conditions characterised by partial albinotic characters may be roughly shown.



Partial Albinism



Coming to a more general discussion of the subject, among facts which have to be taken into consideration the following mentioned by Pearson are of great importance. Leucoderma may occur very early in life and become stationary. Pearson says "the possibility in Leucoderma of very early development followed by a stationary condition, and the fact that babies only gradually develop skin pigment so that congenital unpigmented areas may not be at once noticed, render it not so easy to distinguish partial albinism from stationary leucoderma in a European." Concentration of pigment in the neighbourhood of leucotic patches has been laid stress on as a feature of leucoderma, but it is not invariable. Symmetry and progressiveness and the combination of excess and deficiency are held by Crocker to be the characteristics of leucoderma, but as Pearson says "there can be little doubt that...leucoderma ceases to be progressive in some cases and that in such cases...the increased pigmentation at the borders is wanting." Further the symmetry "may be by no means marked" and the distribution of patches in undoubtedly congenital cases of leucosis may show a considerable degree of symmetry. Evidence of recovery of pigmentation in leucodermic patches is not wanting.

Leucoderma has further been shown to be inherited, and a case due to Dr Joseph Jones has been published in which inherited leucoderma seems "to have culminated in albinism." There thus appears to be no criterion by which any case can be judged to be one of leucoderma or of partial albinism, and the history may yield the only facts of value. For these reasons, any hypothesis to explain albinism must explain at the same time the facts about leucoderma as they are known.

In dealing with the pathogeny of the condition I follow largely Pearson in his presentation of various theories. The normal formation of skin-pigment is a question around which much conflicting opinion has grown. The site of the formation of the pigment has been variously supposed to be in cells belonging to any or all of the primary layers, endo-, meso- and ecto-derm.

Special cells have been described as acting as carriers of pigment from one layer to another and called in consequence chromatophores (Kölliker, Simon, Kerbert, Ehrmann); Ehrmann later considered these cells to be actually the producers of the pigment, and calls them chromatoblasts or melanoblasts. Meirowski's summing up of Ehrmann's views quoted by Pearson is as follows:—

(1) The production of pigment occurs in special cells, the melanoblasts, which are not identical with mesodermal or epidermal cells.

(2) The melanoblasts are products of the middle germ layer, which in part further develop there, grow into the epidermis, and there have an independent cell existence.

(3) The material which is converted into melanotic pigment comes from the blood and is haemoglobin. Haemoglobin is converted into melanotic pigment by the vital processes of the melanoblasts.

(4) Extra-cellular creation of melanotic pigment is not yet demonstrated. True melanotic pigment only occurs in an extra-cellular form by the break-up of pigmented cells.

(5) The transfer of pigment occurs by aid of protoplasmic flow along protoplasmic threads, which connect the melanoblasts with the epithelial cells. For this reason this theory is not an "Einschleppungstheorie" but an "Einströmungstheorie."

(6) Pigment is, at least shortly after its production, a body dissolved in a highly fluid colourless substance.

Unna believes that the pigment granules formed according to Ehrmann's hypothesis pass by way of the lymph stream to the epithelium.

Cohn holds that free pigment certainly exists outside the cells.

Schwalbe believes that epidermal and dermal cells can each produce granular pigment as a result of their individual activity, drawing upon the same source, though independently; he believes that: (i) a pigmentation of the cutis can occur with completely unpigmented epidermis and hair, and (ii) a pure epithelial pigmentation can occur without trace of pigment in the underlying mesoderm. He rejects the chromatophore theory and considers these cells to be transformed epithelial cells.

Kaposi also criticises Ehrmann's views to show that a haemoglobin origin for melanin is untenable. More recently other observers (Meirowsky, etc.) have come to the conclusion that epidermis and cutis pigment can arise independently, and

the melanoblasts of one and the other are independent structures. The nature of melanin has been investigated by a few observers. Hopkins and Cole have isolated a substance as a product of tryptic digestion of proteid which may be the mother substance of the proteinochromes skatol, pyridine and tyrosine. Tyrosine by the action of a ferment can be changed into a substance resembling melanin.

This ferment tyrosinase has lately been found in a variety of species, plants and animals, including newborn rabbits, rats and guinea-pigs.

The above notes on melanin are gleaned from Pearson's observations on Von Furth's summary.

Dyson has recently shown, by means of the bichromate-haematoxylin method of Lorrain Smith and Mair, that pigment is always formed as part of a complex granule which contains lipoid substance. These granules are present constantly in the basal epithelial cells, and are formed there under the influence of the nucleus as a part of the normal metabolism of the cell. The pigment is in origin a lipochrome, the melanin being the chromatic proteid portion after separation from the complex lipoid granule. He found no evidence of pigment formation in the cutis, but showed sections which illustrated the passage of lipoid substances from the epidermis into the cutis along lymphatic channels.

It appears therefore that our knowledge on melanin and its production so far points to the following conclusions:

(1) Melanin is not a direct (and probably not an indirect) product of haemoglobin.

(2) It is the product of splitting of a complex lipoid substance possibly as the result of a ferment action, akin to the formation of pigment from tyrosin by tyrosinase.

(3) The complex granules containing the lipoid substance are produced as the result of the metabolic activity of the individual cells of the epiderm.

(4) The presence of melanin is responsible for skin pigmentation.

(5) Melanin in the cutis is probably derived from the epidermis.

This is as far as knowledge goes at present with regard to melanin. How can we explain its more or less complete absence in albinism, etc.? Pearson sums up "when we consider the relative rareness of complete albinism, of the spotted or splashed condition and of Xanthism, their relatively frequent coincidence in the same stock suggests that these abnormal pigment conditions are not wholly independent, and that as a working hypothesis it is reasonable to suppose that complete albinism, partial albinism, incomplete albinism and Xanthism, all static forms of leucosis, are phases of the same process and are probably linked with leucoderma and possibly other forms of dynamic leucosis. By 'linked' we suggest that they mark the complete, incomplete, local or progressive failure of the same metabolic process, which may never start at all, never start in certain areas, or be imperfectly started, and again being started may fail to maintain itself; further

that every variety of this failure may individually or collectively be associated with certain stocks, which may either show hereditary failure of one phase, of several, or exceptionally of all phases of pigment metabolism."

This hypothesis gives a masterly summing up of the position, warranted, I think, if only in the light of my own series of cases.

If we seek the cause in some inherited defect we might suppose that some pigment-controlling determinant by its absence causes failure of natural pigmentation. Its perfect or imperfect impotence may be a racial feature of certain forms of parental albinism. This impotence may be a racial feature of certain parental stocks or produced by some degenerating influence of the somatic on the germ cells of the individual parent such as must occur in the case of an inherited character arising in the parent as a "sport."

This absence of certain determinants does not carry us very far, for the question suggests itself: how do such determinants act on the normal body metabolism? It has been suggested that some ferment necessary for pigment formation such as tyrosinase is absent.

As Pearson says, "it must however be remembered, (i) that the absence of the ferment in the albino must correspond to some abnormality in the zygote and ultimately to some defect in one or both gametes. This defect can hardly be an absence of ferment. (ii) The materials for development are supplied in utero by the mother, who may be (*a*) herself pigmented, and (*b*) produce at the same time pigmented and unpigmented twins. It would appear that she is thus able to provide the ferment for one and not for the other offspring."

One might postulate ferment determinants. Pearson suggests "that the ultimate difference between the normally pigmented individual and the albino, will be found after all to be one of structure; the failure of the normal metabolic process is due to differential structure in the albino. If there be local absence of ferment it may possibly be that the structure does not permit of its reaching its destination," and mentions in support of this view that albinos may have a considerable amount of diffused pigment in their hair.

He also says that it would be difficult otherwise to understand how in cases of partial albinism the ferment should be confined to some portions of the skin and be wanting in others. Facts gleaned from my own observations which seem to have a direct bearing on some of these points I may here refer to. I should like first to mention some observations on the natural rate of pigmentation in African natives.

Pearson states that a black baby at birth almost resembles a white one in colour, and quotes Dr Strachan*. With all deference to Dr Strachan, I most

* [This does not seem adequately to represent the views of the authors of the *Monograph*, or of Dr Strachan. The reader is referred to pp. 120—124 of that work, where much of the literature on the subject is cited. The point involved is not the impossibility of distinguishing between a just born white and just born black baby, but to the fact that the black pigmentation except on the genitals and some other parts is relatively slightly developed at birth. Ed.]

certainly must differ from him and agree with Dr Pooley, also quoted, when he says that "in newborn babies (negroes) the skin being thinner, the pink of the blood vessels is much more clearly seen, but the skin has an ashy grey colour all the same, the black is there all the time"—a phenomenon which is clearly seen in the still-born and premature births. I do not hesitate to say that a portion of skin of the new-born native of this country could be immediately distinguished from a portion derived from a new-born European child. To give an example, the infant of Private Jumbe, 1st K. A. R., seen immediately after birth, had a skin colour of a pinkish white with a dark *café-au-lait* tint about it, not the dead white as seen in other young albino children; hair of head rather straight and a dark brown in colour, body and limbs covered with very light fine hair of the lanugo type; irides a liquid steel blue. Darkening of the skin occurred rapidly; it was not noticeably light after three weeks, and in three months it was an ordinary "dark" coloured baby.

Specimens of hair from the head and body having the colour as above mentioned were taken a few days after birth. The hair from the scalp was seen to contain bright yellow diffused pigment, and a fair amount of brown granular pigment. The body hairs were very fine and undeveloped, and very fine granular pigment was present.

The pigmentation, then, of the skin (irides and hair) of the native of Central Africa is a progressive process; normally pigmentation is quite marked at birth and thereafter proceeds rapidly, but in a large number does not reach, so to speak, completion till the age of possibly 16 years. This I have noticed with three or four of my younger servants who during the six years they have been with me have darkened very materially.

This production of pigment as the result of metabolism in certain cells might be likened to the production of the salivary ferments by the salivary glands. The cells are there in the skin ready for their work in the foetus just as the cells of the salivary glands are, but the latter do not begin to produce their ferments till they are needed (for the digestion of certain foodstuffs); in the same way the skin of the young foetus is unpigmented, and it is only when pigment is about to be needed that it is formed. During the few days after birth there is a call for its rapid formation and it is produced.

The stimulus for this rapid formation is probably light rays or ultra-spectral rays acting indirectly by means of a ferment, though, now that pigmentation is a racial characteristic, the tendency for the process to start and go on is represented in the germ-plasm of the parents. This inherent tendency to produce pigment is borne out by the fact that the latter was present in the hairs removed from a dermoid cyst (*vide supra*).

That depth of pigmentation is conserved as the result of such a physical cause as light I have no doubt, as the following observation will serve to show. I held a medical inspection of the 1st Battalion of the King's African Rifles the day after

part of the Battalion had returned from Somaliland. I was surprised to find when the Battalion as a whole stripped that the men who had been on foreign service were many shades darker than those who had remained in the Protectorate of Nyasaland. The Somali men were as black as any native I have ever seen, and by comparison the Nyasaland men looked like members of a yellow skinned race. The reason for this difference was that in Somaliland all fatigues had been done bared to the waist, while the men remaining in Nyasaland had not been without regimental clothing (khaki tunic or blue jersey) for years.

I obtained a similar result by keeping several turns of bandage round the chest of a native for eight weeks.

Again, I would refer to my observations on the skin colour of the penis. One may say that normally the ensheathed glans penis is not deeply pigmented; the pigmentation of the partially covered glans is proportional to the want of cover. The glans of a man who has been circumcised is invariably black. Therefore though always pigmented to some degree because skin pigmentation is a racial characteristic, the process is only completed as the result of exposure in the majority of cases. Special notice must be taken of the case of albinism of the penis; wherein, after circumcision at the age of 26 years, the skin of the glans, which was absolutely albinotic and would doubtless have remained so all the man's life had he not been subjected to operation, developed a spot of pigmentation a year later. How could this case be accounted for on the theory of structural defect*? It is a fact worthy of remark that the penis should be the commonest site to find a spotling albinism and that it should occur in close on 4°/₀ of 379 men taken at random; excluding the circumcised, it occurred in nearly 6°/₀.

In a large number of albinos we have seen there is a marked ability to form pigment (*vide* spotted albinos, and those of Class IV, who develop a certain amount of pigment in the skin but not in the hair and again those in whom pigmentation is only delayed, cases C 11, C 12 Sawali) which does not appear to point to defective structure of the skin, the explanation favoured by Pearson, but would rather suggest the action of some internal secretion. The hyperpigmentation of Addison's disease is due to the perverted action of the suprarenal glands which are commonly the seat of the destructive lesions in that disease, and it seems quite possible that normal pigmentation in negroes is due to a somewhat similar cause; light may act not directly on the skin cells but on some tissue or substance which determines the formation of pigment in the skin.

Many of the characteristics of persons living in tropical countries are akin to symptoms occurring in suprarenal insufficiency.

With regard, however, to the factor of abnormality of skin structure brought forward by Pearson, I would again refer to the conditions as seen in the sections of

* [I would venture to suggest that the very facts that the pigment developed in a spot only in this case, and that pigment occurs in localised patches only in piebalds, or in freckles and isolated locks of hair in otherwise complete albinos do indicate a differential structure; the *local* absence of a ferment—without a cause for its absence—seems to me an inadequate explanation of leucosis. Ed.]

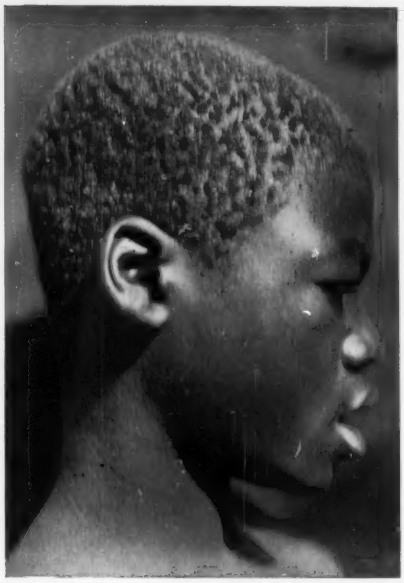


Fig. 1.

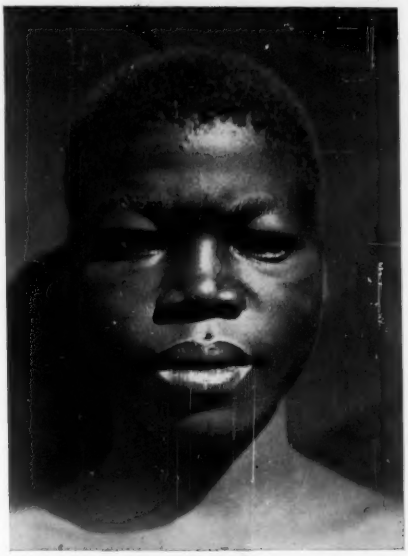


Fig. 2.

Sawali of Ntiya, Mlumbi. Case of Xanthism. See p. 346.

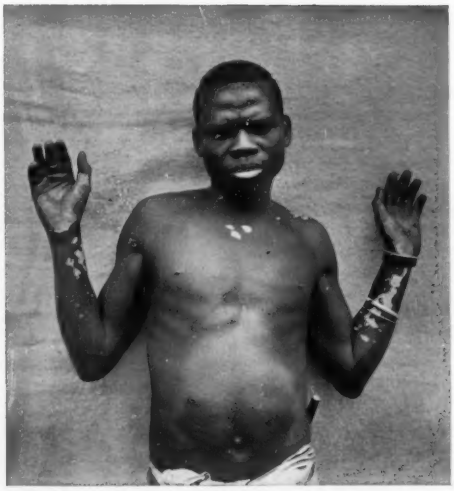


Fig. 3. Ouda of Checkiwere's. Case of Leucoderma. See p. 353.

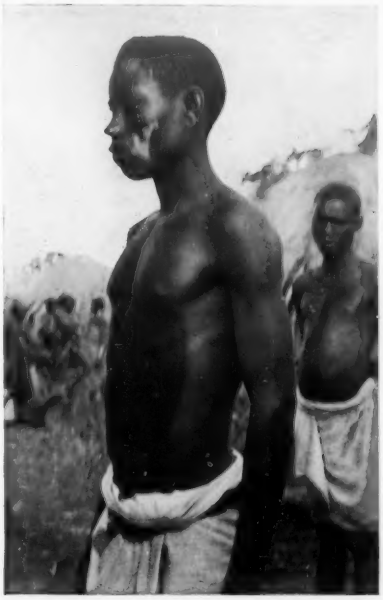


Fig. 4. Daus of Chimwai Village, Dwangwa River. Spotlings. See p. 348.

Fig. 5. Girl H., from village on Lake shore in West Nyasa. Leucotic area sharply limited along midline. See p. 347.

Fig. 6. Daus of Chimwai Village, Dwangwa River. Spotling. See Plate XII (4). See p. 348.

Fig. 7.

Albinotic penis not referred to in text.

Fig. 8.

Lijuni. Leucosis of glans and inner surface of prepuce after circumcision. See p. 351.

Fig. 9. Binali. Leucosis of glans and prepuce. See p. 351.

Fig. 10. Licheta, an Angoni of Dedza, Central Prison, Zomba. Case of Ziemann's "Melung." See p. 355.

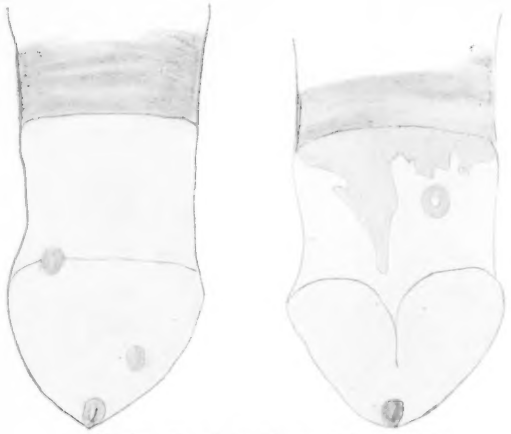


Fig. 11. Matesi, an Atonga. See p. 351 (*c*).

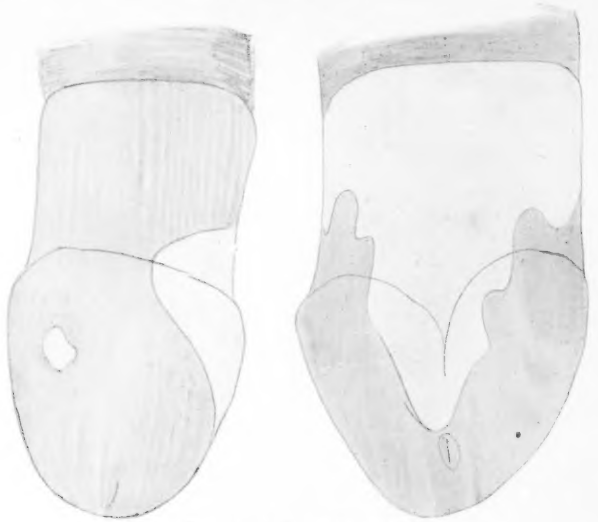


Fig. 12. Jim. See p. 351 (*d*).

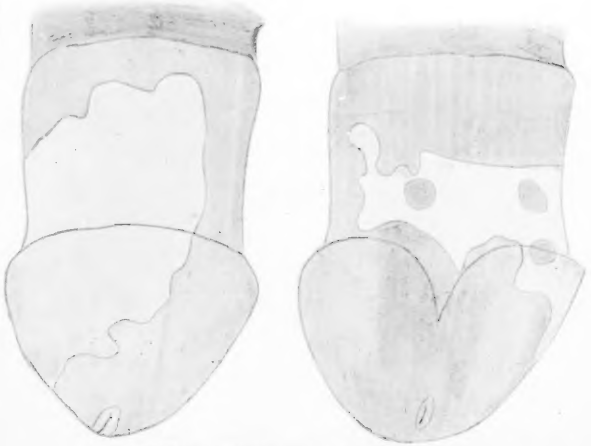


Fig. 13. Chizizu, Yao. See p. 351 (*e*).

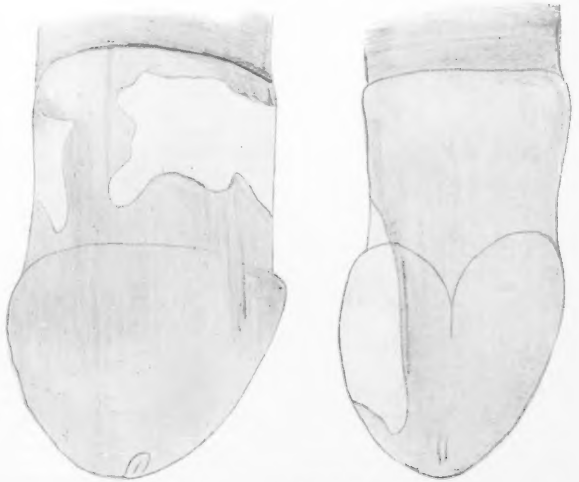


Fig. 14. Lief. See p. 351 (*f*).

SPOTLINGS OF THE PENIS.

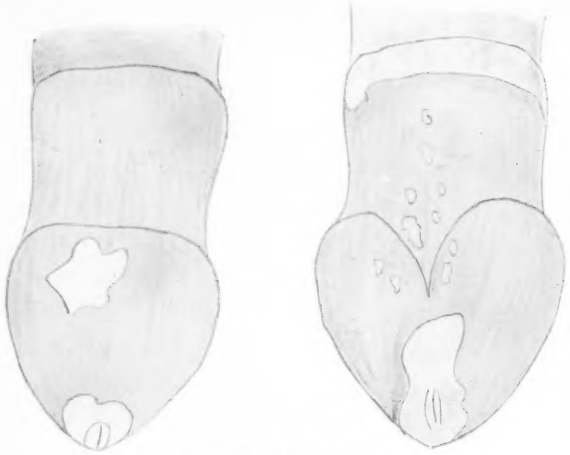


Fig. 15. Chiwia. See p. 351 (*g*).

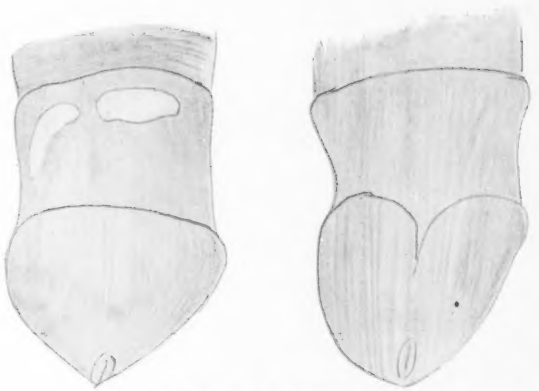


Fig. 16. Chivia. See p. 351 (*h*).

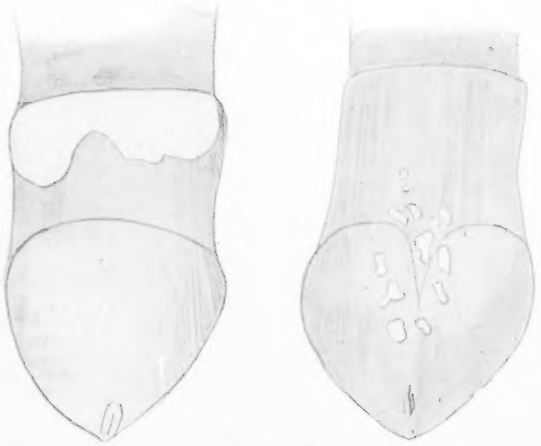


Fig. 17. Naamon. See p. 351 (*i*).

Fig. 18. Magombo. See p. 351 (*k*).

SPOTLINGS OF THE PENIS.

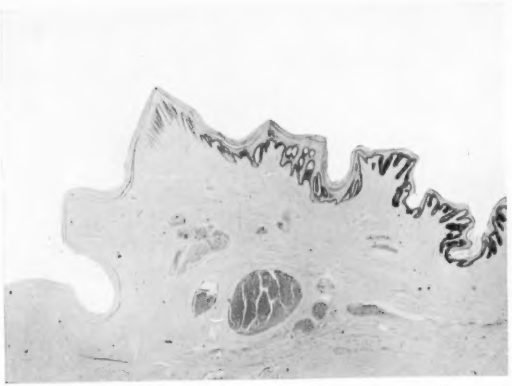


Fig. 19. ×27. Foreskin of Negro to show transition from normally pigmented skin to albinotic patch.

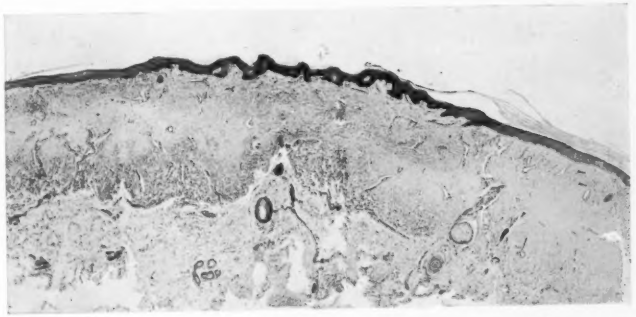


Fig. 21. ×24. Microphotograph of skin of albino showing a freckle (corrugated portion) in an albinotic area.

Fig. 20. ×267. The same as (19) enlarged and reversed; to show transition with gradual disappearance of melanin granules from the deepest cells of the stratum malpighii.

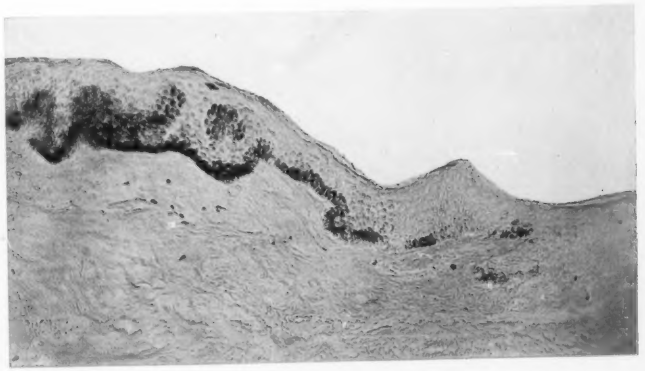


Fig. 22. ×267. Freckle in (21) enlarged to show melanin granules in deepest cells of stratum malpighii, constituting the freckle, and to indicate how these granules gradually disappear as transition is made to albinotic skin.

Fig. 23. Normal Native, Moyichandi and Sikumbiri from left to right. Grades of albinism in Nyasaland Natives. See p. 346.

Fig. 24. Chibwana, an albino with mother and sister, from Chikala. See p. 343.

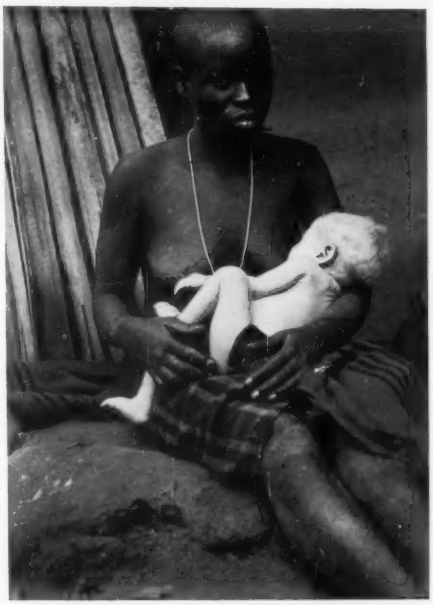


Fig. 25. Alice, an albino baby, and her mother from Chikanji's village. See p. 339.

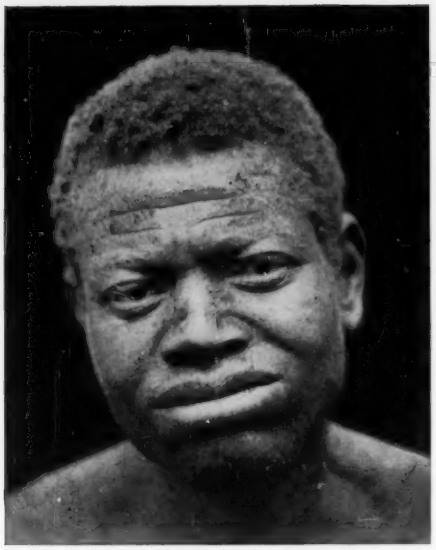


Fig. 26. Head of Pingo, an albino from Chitalu. See p. 341.

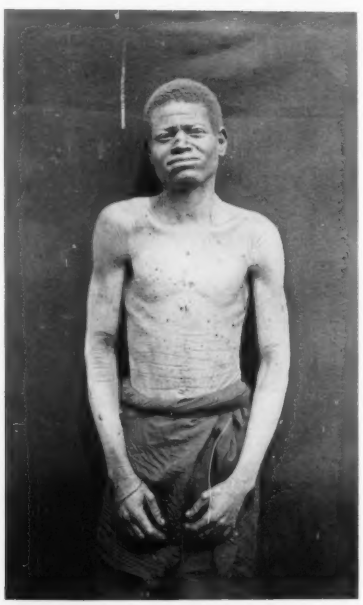


Fig. 27. Pingo, an albino from Chitalu. See p. 341.

Fig. 28. John, an albino from Mwandanas. See p. 340.

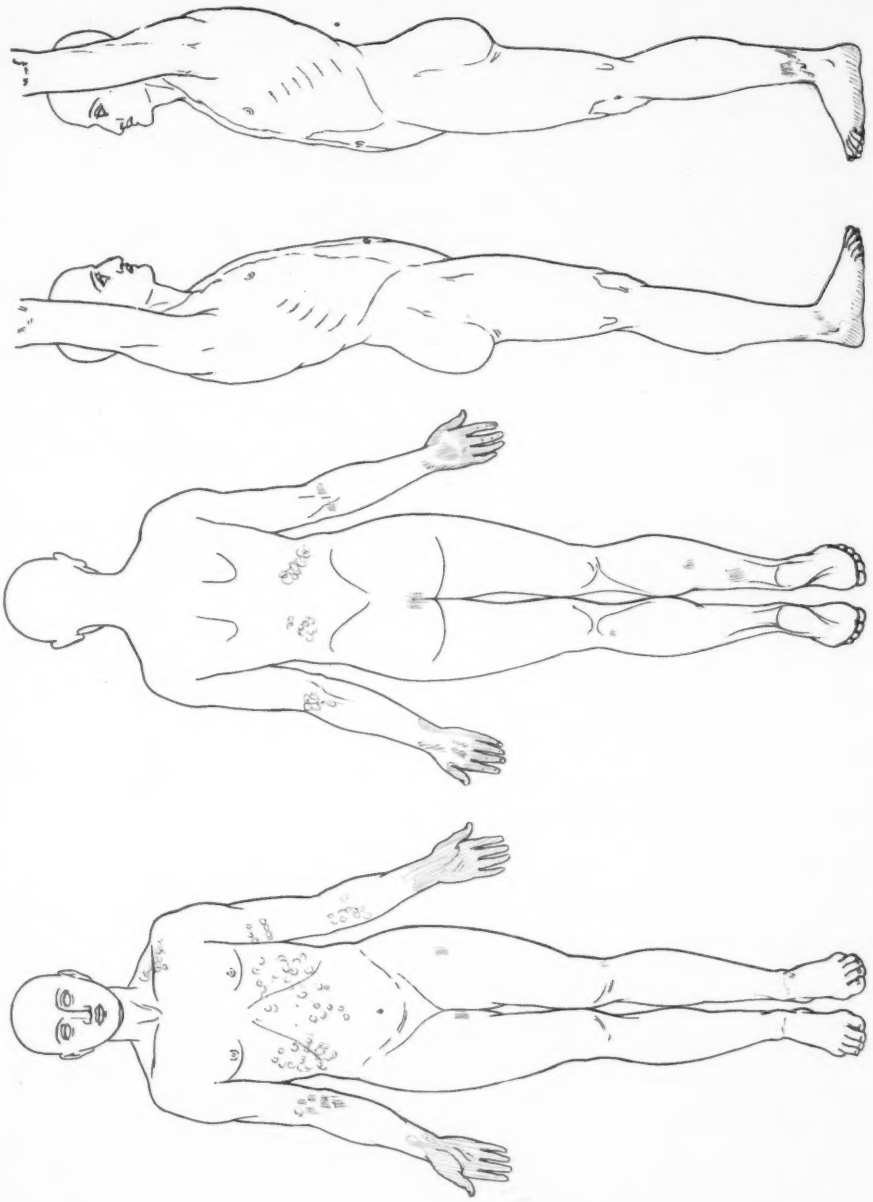
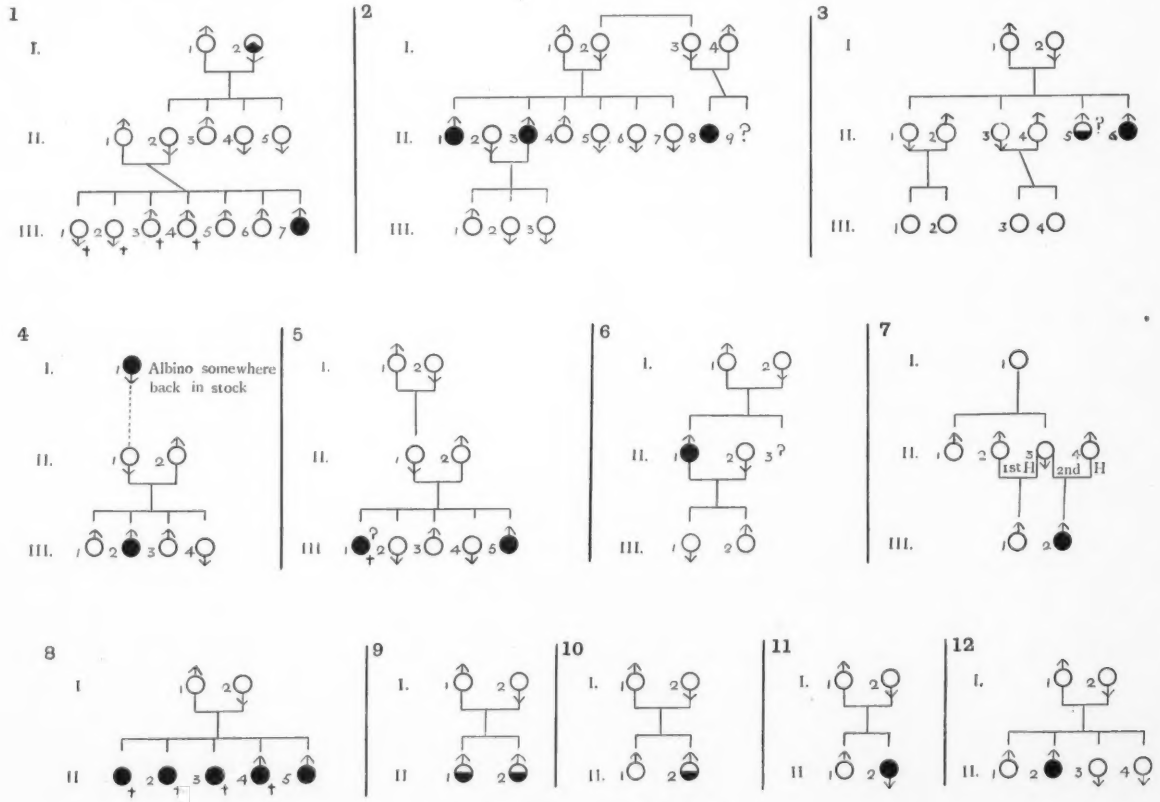


Fig. 29. Chisfufu (see p. 355). Special type of Leucoderma, Ziemann's "Melung."



Short Pedigrees of Nyasaland Albinos.

a pigmented spot from an albino, and also to the association of an unusual development of lanugo and of defective teeth with albinism.

The condition of the teeth suggests enamel deficiency, and is one which I did not meet with when examining the teeth of 1500 natives of all ages (not albinos) for statistical purposes.

One of the interesting points which has been brought to light by the investigations of Pearson and others is that in albinotic hair, while granular pigment is absent, diffuse red or yellow pigment is present, and the same is true of some kinds of red hair among Europeans. The relation of this diffuse pigment to granular pigment has not however been I think generally recognised. From the microscopical examination of the various hairs above described I think there can be little doubt that the granular pigment is formed from the diffuse pigment by some process allied to precipitation (compare hair from new-born infant child of Private Jumbe, from Mwana Ngala, from Pamandhe, also from Sawali and Moyichandi)*.

Loss of colour may be accompanied by a reversed process (compare hair from Kause, an old female lunatic).

A similar process may take place in the skin, as evidenced by the band of diffuse colouration beyond the area of granular pigment found in the section of prepuce (Lijuni).

The plan of the localised leucotic patches may be palaeogenetic as suggested by piebalds with white belly markings and flare, or there may be a segmental distribution (see case of girl H. in whom the area is limited strictly by the mid-line).

One believes therefore that pigmentation is due to an internal secretion, that light and other climatic conditions are determining factors, that a ferment may play some part, that the pigmentation of the skin is due to melanin produced in the cells of the epidermis, and that therefore structure also must be taken into account, that in albinism in its various grades and in dynamic forms of leucosis one or other or several of these factors have to be taken into account.

Addendum. One may say that in ordinary natives the colour of the iris is always some shade of brown. There is one exception. The iris in a few otherwise ordinarily dark natives may be of a greenish colour with no element of brown, a very striking feature, and known as "jeri-jeri" by the natives, who say it resembles the eye of a cat.

* [It seems difficult to establish such a conclusion until very elaborate chemical investigations of the two types of pigment, lipochrome and melanin have been made. The microscopic investigation of hundreds of samples of hair, albinotic and non-albinotic, are given in Chapter VIII of the *Monograph*, but they tell so far as much in favour of the independence as of the dependence of the two types of pigment. ED.]

ON THE EXPECTATION OF LIFE IN ANCIENT ROME, AND IN THE PROVINCES OF HISPANIA AND LUSITANIA, AND AFRICA.

By W. R. MACDONELL, Hon. LL.D. Aberdeen.

The data on which the following paper is based have been extracted from the *Corpus Inscriptionum Latinarum* of the Berlin Academy. For Rome I have examined Vol. VI. parts 1 to 4 (2), for Hispania and Lusitania Vol. II. and its *Supplementum*, also the *Ephemeris Epigraphica* VIII. and IX. 1/3, and for Africa Vol. VIII. and its three *Supplementa*.

Rome—(a) The Civil Population.

I have divided the Roman inscriptions into two classes, (*a*) those relating to the civil population, males and females being shown separately, and (*b*) those relating to the soldiers of the garrison.

Method of stating Ages. In the great majority of adults the age is given in years only, but in a considerable number the months and days are added, in a few cases even hours. Children's ages in the majority of cases are given in years, months, days and sometimes hours. Also on the soldiers' tombstones we frequently find their ages recorded to days, four of them even to hours, and amongst these we find natives of Thrace, Pannonia, etc., which points to accurate registers of births having been kept even in distant parts of the Empire. Some of the inscriptions record the ages with extreme exactness, e.g. No. 2771, 80 years 8 hours; No. 17677, plus minus 25 years 2 months 24 days; No. 20670, 86 years 1 hour.

This accuracy of statement is no doubt largely due to the requirements of astrology, which we know was widely practised in ancient Rome*; possibly also

* No. 27140, the inscription on the tombstone of a boy, who died at the age of 4 years 13 days, contains a reference to an astrologer who had evidently forecasted a long life for the child. The deceased is supposed to address the passer-by in half a dozen lines, which conclude thus:

Non igitur, lector, lachrimes: [de]cepit utrosque
Maxima mendacis fama mathematici.

it is in some degree due to the operation of the ordinance of the Emperor Marcus Aurelius, who was the first to introduce an official registration of births in Rome and the Provinces for the special purpose of establishing the status and age of the people when required*.

But, as I have said, in the great majority of the inscriptions the age is given in years only, and in many cases it was evidently not known accurately, probably no record of birth having been kept, or the record having been lost or destroyed. An examination of Table I will make this clear. It will be seen that after the 15th year the frequencies are heaped up on ages expressed by multiples of 5; e.g. at 25 years we find 129 deaths of males, but at 24 and 26 only 57 and 34 deaths respectively. Soldiers' ages are treated in the same way. Perhaps the explanation is that in many of these cases the age was not known exactly in years, but that the number of *lustra* of five years which the deceased had lived would be known fairly correctly, and would thus furnish the basis on which the number of years was calculated. Of course we cannot say how such a method of computation, if it existed, would be worked out in practice; if for instance it was known that no long period had elapsed since a person had completed his 6th lustrum, his age might conceivably be recorded as 30, if a considerable period had elapsed, as 35. Whatever the real explanation may be, it is evident that the practice causes a difficulty which will be obvious from an inspection of the diagrams on Figs. 1—3: the polygons showing the expectation of life in the ancient world present a jagged appearance in marked contrast to the smooth, continuously descending curves which represent the data for modern times. But these data are subjected to smoothing before publication. The difficulty might have been got over, as Mr Palin Elderton has suggested to me, by adding together the deaths recorded at ages 18, 19, 20, 21 and 22, calling these 20 (and similarly for the other groups) and then redistributing them. The same result, however, can be attained fairly accurately and with a saving of labour, by supposing the jagged polygons replaced by continuous curves, and such curves can be readily placed on the diagrams.

Date of the Inscriptions. Few of the inscriptions which record age at death give us a direct clue to the dates at which they were erected. Some that were found in the "Monumenta" of families and households of historical personages (Livia, Nero, Drusus, Marcella, etc.) can be assigned to the early Empire, and a few, mainly Christian of the 4th to 6th centuries, give the names of the contemporary consuls, and can thus be dated exactly. In one case, No. 9919, the name of the Emperor, Mauricius (A.D. 582—602), and the year of his reign are given. It is possible that scholars can date the inscriptions from the form of the letters, the spelling, etc., but as I am not aware of this having been done, I must leave the point unsettled and would suggest with some hesitation that the great mass of the inscriptions belongs to the first three or four centuries of our era.

* Marquardt, *Das Privatleben der Römer*[2], p. 86.

Status of the Deceased. A considerable number of the inscriptions record the status of the deceased, and a somewhat rough examination gives the following results for males*:

Servi	121
Vernae	164
Alumni	65
Liberti	390
Officiales and Artifices	290
Agitatores and Histriones ...	20
Patroni	64†
Ordinis equestris	19
Ordinis senatorii	8
Sacerdotes, haruspices and calatores	17
	1158

The mere fact that a person was considered worthy of a gravestone and inscription at all, would seem to indicate that the deceased did not belong at all events to the dregs of the people, and I am therefore inclined to believe that we are here dealing with a population which in status was above the very poorest and consisted largely of the slaves and freedmen, with their wives and families, of the well-to-do classes of Rome.

Expectation of Life. A reference to Table I will show how this is calculated. By way of illustration I will take Roman males. I start with a population of 4575, which I call l_0, using the actuarial symbol; of these 74 died before completing their first year, therefore 4501, or l_1, completed their first year; of the 4501, there died before completing their second year 197, therefore 4304, or l_2, completed their second year, and so on. Then the complete expectation of life at any year x is defined as

$$\frac{1}{2} + \frac{S^n{}_{x+1}(l)}{l_x}.$$

For example, at the year 1 it is

$$\frac{1}{2} + \frac{4304 + 4086 + \ldots + 1}{4501} = \frac{1}{2} + \frac{95185}{4501} = 21{\cdot}65.$$

The values of the expectation are shown by the curves on Fig. 1, and for purposes of comparison I have added the curves showing the complete expectation of life in modern England and Wales, based on the mortality of the general population, not of healthy lives only, in the years 1891—1900. These data are of course smoothed by the Registrar-General's officers before publication.

* When the indices to Vol. VI. of the *Corpus* are published it will no doubt be possible to extend and correct these figures.

† It is worth noting that these seem to have been a long-lived class, the average age of the 64 being 62—63 years.

From Figure 1 we see that, contrary to modern experience, the curve for females always lies below that for males until about the age of 75; after that age the two curves practically coincide. For the first 20 years the male curve remains fairly level, while the female curve goes steadily down, until the difference between the two reaches a maximum about the 20th year; both remain level for the next 10 years, and then they gradually approach, the female curve rising until about 45 and thereafter falling. If our data had been ampler we should no doubt have had curves of a steady downward slope, as in the case of the African expectation.

The most striking feature of the diagram is the very low expectation of life in ancient Rome, as compared with that of the present day, up to the age of 40, and especially for the first 20 years of life. This might be accounted for to some extent if we had reason to think that monuments in memory of persons who died before reaching 20 were likely to be erected in relatively greater numbers than in the case of older people. But I know of no reason to suppose that this was the case; indeed the probability seems to be the other way, for we might reasonably assume on general grounds that the older a man was the more likely he would be to make his mark in the social group to which he belonged, and be considered worthy of a tombstone and inscription. In the absence of definite information I think we may conclude that there was a relatively heavy mortality at the earlier ages, due probably to circumstances peculiar to Rome, for, as we shall see, the expectation of life was much higher in the earlier decades of age in the Provinces than in the Capital.

Between 50 and 60 ancient and modern expectations are very much the same, and after 60 the ancients had the advantage. The latter is a remarkable fact, but it is just what we should expect if the view that there was a heavy mortality amongst the young is correct; by severe selection of the young the survivors would be of specially strong physique, and would therefore show a high expectation of life.

Married Women. Out of the total of 3490 females I have noted 897 whom the inscriptions specially record as having been wives or mothers, and I find that up to the 20th year their expectation is greater than that of all women, the difference ranging from $4\frac{3}{4}$ at the age of 10 down to 1 at the age of 20; but after the 25th year it is less, the maximum difference being 2·8.

In connection with this question, it would have been interesting to know at what ages the Roman women married, but unfortunately I have found only 59 inscriptions from which this information can be ascertained. These 59 record both age at death and duration of marriage; the facts are shown in Table II. The first and last entries look doubtful, but the others seem reasonable, and would point to marriages at 10 to 20 having been quite usual. This custom of early marriages might explain to some extent the low expectation of life for women at that period, but little weight can be placed on this conclusion, as the data are so scanty.

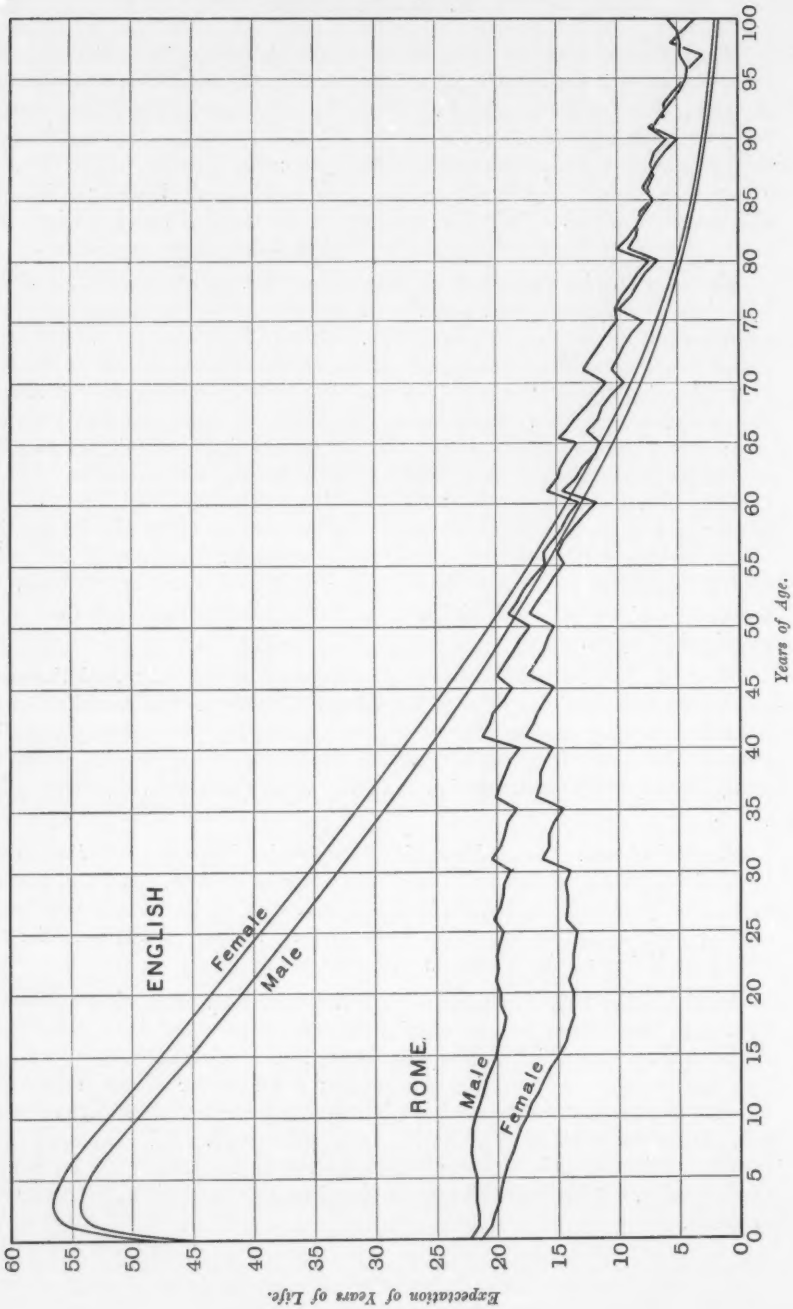


FIG. 1. Expectation of Life in Rome.

Married Men. For the age of men at marriage the data are still scantier; I have found only 29 cases, and in these the ages at marriage run from 15 to 63, 11 of them lying between 17 and 20.

Rome—(b) Soldiers in Garrison.

The data have been collected from inscriptions 2424—3922 and 32668—33038. They record the nationality of many of the soldiers, and it appears that they came from distant parts of the Empire—Dacia, Thracia, Pannonia, Egypt, Libya and so on, as well as from various parts of Italy itself. Indeed, if we may judge from these inscriptions, the great bulk of the garrison was recruited mainly in the Danubian provinces and the north of Italy. I have therefore dealt with the soldiers separately—there are 607 whose ages are recorded—and find that as regards expectation of life they compare unfavourably with Roman males, and from 25 to 50 even with Roman married women. But no very satisfactory comparison is possible owing to the scarcity of available inscriptions.

The age of soldiers on entering the army can be found, as the inscriptions often record both age at death and length of service. Fortunately a considerable number of such inscriptions have come down to us, viz. 400 in Rome, and particulars will be found in Table III. From these figures it seems probable that the majority of the garrison soldiers joined at ages from 16 to 23, the greatest number centring round 19; but remembering the absence of precision in stating ages we can only look at the figures broadly and conclude with some probability that the hardships and risks of a military life, the change from the country to the capital, and perhaps the youthful age of the recruits had an important influence on the mortality.

Amongst the soldiers were some very old men, 19 of them ranging in age from 70 to 105; they were no doubt attached to the army in some sort of official capacity, apparently after receiving their formal discharge, if we may judge from No. 3453, which records the death of a soldier at the age of 70, and states that he was "probatus" at 22 years, served for 23, and lived 24 years 3 months and 11 days after receiving his discharge ("post missionem"). The length of service was sometimes very long; three inscriptions record 43, 51 and 55 years.

Hispania and Lusitania.

From the *Corpus* and *Ephemeris* I have extracted the ages at death of 1111 males and 885 females. I have not kept a record of the social status of this population, but from an inspection of the index in the *Supplementum* I find remarkably few set down as freedmen or slaves; it may not have been the custom to give this information, or we may be dealing with a population of higher social status than the Romans.

In very few of the inscriptions are the months and days recorded, and the same piling up of frequencies at ages represented by multiples of 5 occurs as in Rome.

There is a very marked paucity of deaths in childhood, and a relatively large number of deaths in very old age—two at 115 and one at 125 are specially noticeable. The result is that the expectation of life in these provinces, both for males and females, is far higher than in Rome for the first 30 years of life, the difference decreasing in the case of males from $17\frac{1}{2}$, and in the case of females from 13 at birth to $5\frac{1}{2}$ at the age of 30; from 30 to 45 years of age it continues to decrease, and in the period 45—75 it is about the same, the small difference being in favour of Rome, but after 75 it is again higher.

Up to 60 years of age the expectation of life of females is less than that of males, the difference varying from about 6 to 2; it is then about the same for the next 15 years, but from 75 to 95 it exceeds that of the males. From 90 onwards, however, no weight can be placed on the figures, as only five females lived beyond 90. (See Fig. 2.)

As compared with modern lives the expectation in the case of males is very much less up to 40, a little less from 40 to 50, about the same from 50 to 60, and from 60 onwards it is higher; in the case of females it is very much less up to 50, considerably less from 50 to 60, about the same from 60 to 70, and from 70 onwards it is higher. (See Fig. 2.)

Africa.

Here, fortunately, the data are more plentiful, there being 6238 males and 4459 females, and in consequence the polygons of expectation are much smoother, but before discussing the latter I have to make a few preliminary remarks which raise points of some interest.

Differences of Reading. As usual the ages are almost always given in Roman numerals (rarely in words), and when the stones have been injured or weathered or lie in inaccessible positions, naturally the numbers are difficult to read and are variously given by different observers. I have usually adopted the latest reading, or the one that seems attested by the best authority.

These discrepancies may arise in various ways; the most common in the African inscriptions are the following:

I and X in excess or defect, of frequent occurrence

I for V, e.g. XI for XV
I „ X, „ LXI „ LXX
I „ L, „ IX „ LX
V „ X, „ XXV „ XXX
X „ V, „ LXX „ LXV

V and L in excess or defect, rare.

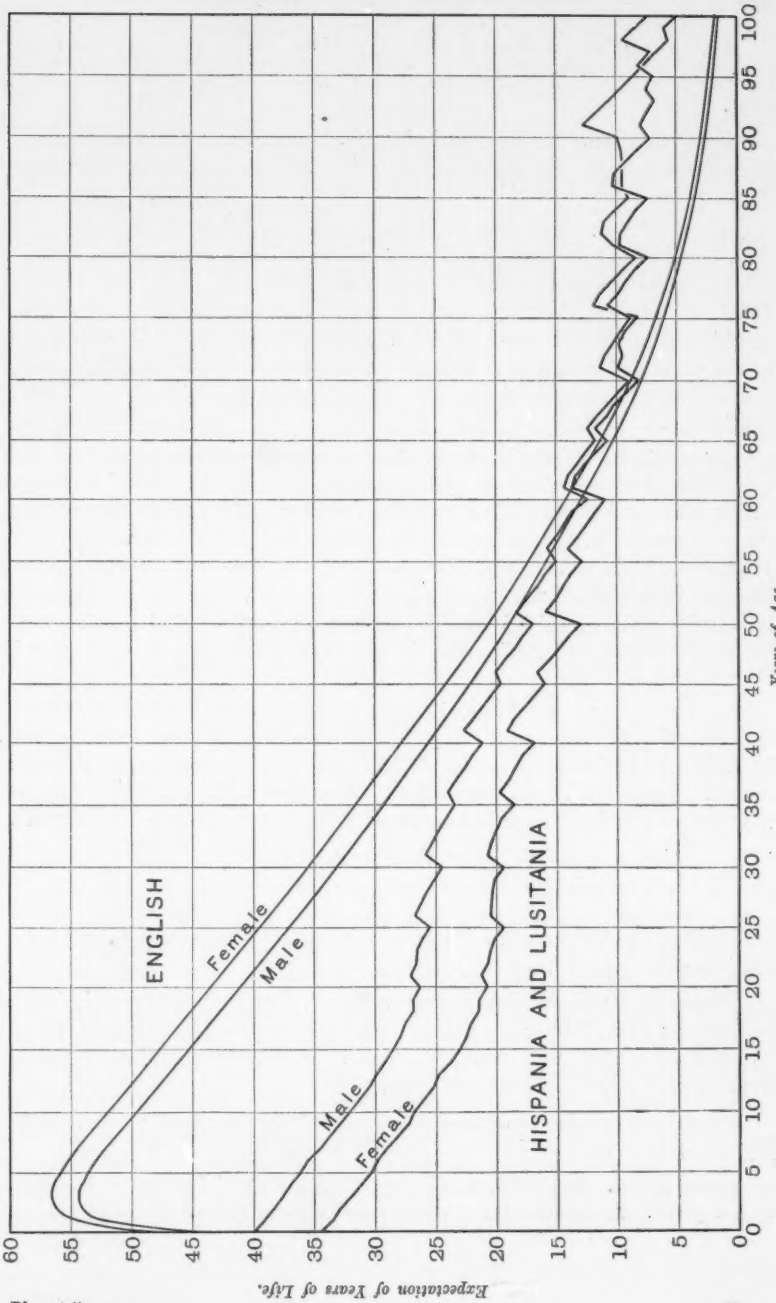


FIG. 2. Expectation of Life in Hispania and Lusitania.

Sex. There is sometimes a difficulty, chiefly with Punic and other native names, in determining the sex, and in consequence I have omitted all doubtful cases.

Size of Families. On one inscription, No. 17463, it is stated that the deceased were the father and the mother of 12 children, from which it may perhaps be inferred that families of this size were unusual.

Record of Age. The ages are given in the vast majority of cases in years only, but occasionally months and days and even hours are added; 12794 gives the age with extreme precision: "anno uno M VIII diebus XX noctu una orabus IIII." The age of Christians seems to have been stated as a rule with greater precision than that of non-Christians: PM (i.e. plus minus) is often prefixed to the years, and months and days are relatively more frequently added; also the date of death in terms of the year of the province is often given on the Christian inscriptions.

Centenarians. It will be observed that I have recorded ages up to 132, but I have noted four inscriptions giving the ages as 140, 155, 160 and 170 years, which I have rejected as being incredible. It is a question whether the symbol for a hundred, viz. C, does not in such cases stand for *circiter*. In one case, 11902, where the C seems to have been written as a small letter above the base-line of the tens, °XXX, I have taken the age as 30. 8008, erected by a father in memory of a son, which I have not included, has VA *CV*, and the editor notes "fortasse circiter quinque." Also in 3934 the editor expands *CIR XXXV* into *cir*(*citer*) *XXXV*.

In 9106 the age of a female is given as 120 years 5 months and 25 days on the authority of Wilmanns; here the interpretation of C as *circiter* seems to be excluded by the completeness of the record and we may accept the age as correct. Perhaps I should have taken 120 as the maximum limit of age, but the few cases which I have taken above 120 affect the result very slightly.

As against the probability of those very advanced ages I may quote from 11594—the inscription on the tomb of a man who died at the age of 82 years 7 months—these words: "non digne cito vita caruisti, vivere debueras annis fere centu'," which seem to indicate that 100 was popularly considered the maximum limit of life.

Causes of Death are hardly ever assigned, but these two inscriptions are interesting: 9048, "duos una dies et *pestis* acerba abstulit hos pueros"; 18792, "O non ut meruit *pesti* vita functus est." 9050, "quae vixit sine *febribus*," would point to the prevalence of fever.

Several cases of violent death—interfectus, gladio percussus, a tauru deceptus, jugulatus, ferro petitus—have not been included.

Social Status. In the great majority of cases the social status of the deceased is not given. A considerable number were soldiers of various ranks, but their

length of service is seldom recorded; slaves are not uncommon—in two "sepulcreta familiae domus Aug. Carthag.," 331 males and 215 females have their ages recorded, and I presume most of these were slaves or freedmen, and slaves are mentioned elsewhere, but very few freedmen. There are a few pagan priests and priestesses, and a considerable number of Christians appear, their dates extending from the 3rd to the 6th century A.D.

Frequencies. There is the usual piling up of frequencies at ages denoted by multiples of 5, but the effect on expectation of life is not so marked as in the case of Rome and Hispania.

Expectation of Life. In Africa the conditions were much more favourable to longevity than in Rome and Hispania.

Up to 40 years of age the expectation for males was not more than 3 above that for females, and after 40 it was almost exactly the same. As compared with Rome, the expectation for both sexes was higher at all ages, the excess ranging from 26 for males and 24½ for females at birth, to about 5 at the age of 60; as compared with Hispania it was higher at all ages up to 90, especially in the case of females, the excess ranging from a maximum of about 12. As compared with modern English the expectation is lower for the first 30 years of life, ranging downwards from about 8 in the case of males and about 11 in the case of females, but after 40 it is higher and goes on increasing until the end.

Conclusions. Even allowing for the scantiness of the data we may draw the following broad conclusions:

1. The evidence of the inscriptions brings out very clearly the extreme unhealthiness of ancient Rome, and on this point it agrees with the literary evidence*.

2. Leaving out of consideration ages above 75 we see that, contrary to modern experience, the expectation of life of females in Rome and Hispania was lower than that of males; in Africa there was little difference between the sexes in this respect, but the males had a slight advantage up to 40 years of age. This would point to special influences adversely affecting the health of females in the Roman empire which no longer operate in the modern world.

3. The expectation of life in Rome and Hispania, especially in the case of females, compares very unfavourably with that of modern England at the early ages, less unfavourably in middle age, but in old age it is higher, owing perhaps, as I have suggested, to severe selection in early life.

4. In Africa the expectation of life was remarkably high, especially after 40 years of age, and may be due in some degree, not only to climate and strict selection in childhood, but also to the considerable influx of colonists from Italy which

* Friedländer, *Sittengeschichte Roms*[8], I. 39 ff.

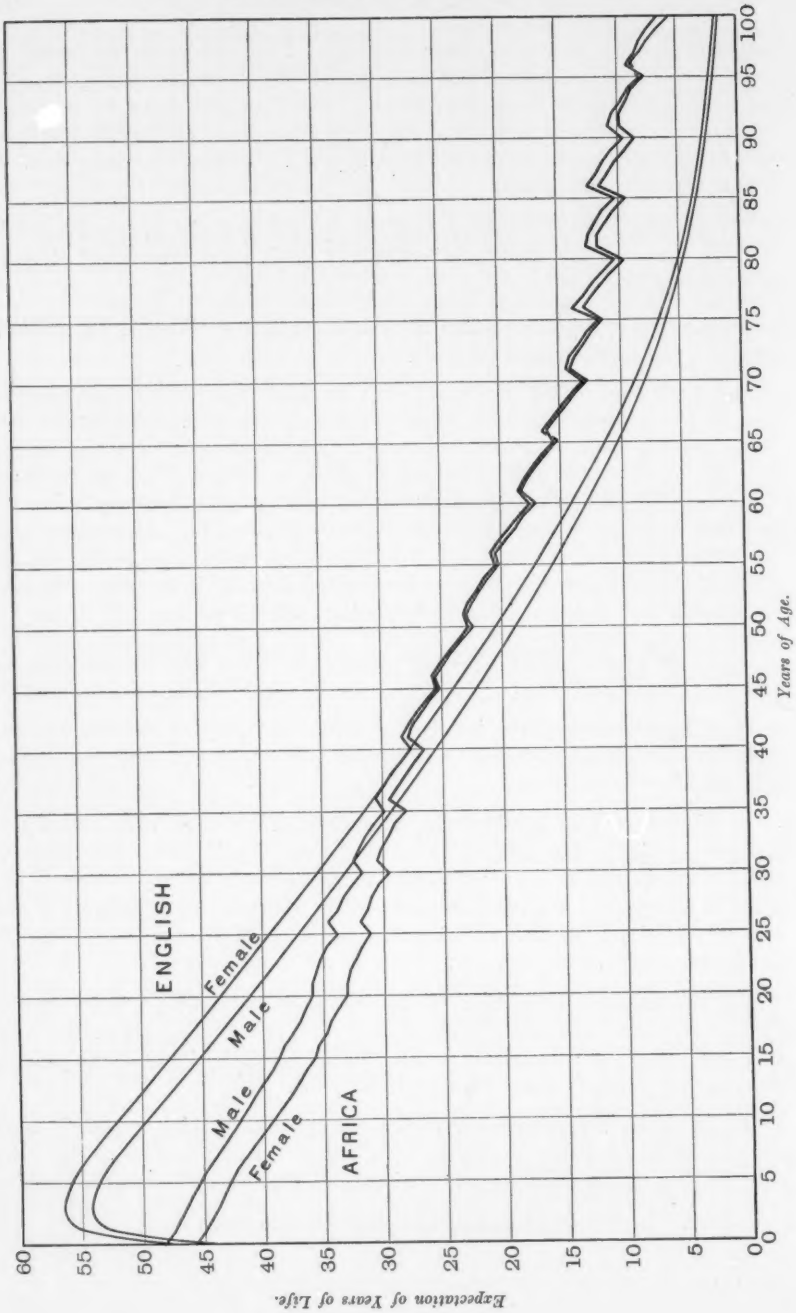


FIG. 3. Expectation of Life in Africa.

took place in the time of Caesar and the early Empire*—for we may reasonably suppose that the colonists were a selected class, possessed of vigour and enterprise, qualities which would be inherited more or less by their descendants—and also to the fact that a large proportion of the population must have been engaged in the healthy occupation of agriculture, for we know that Africa rivalled Egypt as a source of supply of grain for the markets of ancient Rome†.

Note. After preparing the material for the Roman and Spanish part of this inquiry I found from the *Berliner Philologische Wochenschrift*, Vol. 24, p. 604 (7 May 1904) that Professor A. de Marchi published a paper in the *Atti dell' Accademia di Padova*, 1903‡, on the average duration of human life in antiquity based on the inscriptions in Vol. VI. of the *Corpus*. He seems to have gone over the same ground as I have done as regards Rome, and has also dealt with *Gallia Cisalpina*, where he has found a much smaller mortality amongst children than in Rome; in this respect it is interesting to find another province agreeing with Hispania and Lusitania and Africa. I regret that I have not seen Professor de Marchi's paper; coming from so distinguished a scholar it carries an authority to which the present essay cannot lay claim.

* Even before Caesar's time, ever since Rome subdued Carthage, a sporadic emigration of Italians into North Africa had been going on (J. S. Reid, *The Municipalities of the Roman Empire*, Cambridge, 1913). Professor Reid points out, however, that "emigration on anything like the modern scale, or even on the ancient Greek scale, was unknown to the Romans," and with regard to Roman Africa he writes: "The impression that must be produced by a scrutiny of the evidence is that but a minute fraction of the population could claim Roman descent." (See page 316 of his book.)

† Mommsen, *Römische Geschichte*[3], v. 647, 651.

‡ The reference appears to be incorrect as no such paper could be found in the *Atti* in a careful search of the volumes at the British Museum.

TABLE I. *Number of Deaths at each Year of Life in Rome and the Provinces.*

Years completed at Death	Rome		Hispania and Lusitania		Africa	
	♂	♀	♂	♀	♂	♀
0	74	46	4	2	32	16
1	197	127	6	6	60	44
2	218	95	10	4	56	41
3	185	131	10	5	63	46
4	188	117	5	6	49	39
5	202	99	9	13	56	52
6	176	91	3	6	39	27
7	142	99	5	5	42	30
8	132	89	6	3	46	21
9	107	78	8	13	36	28
10	91	81	8	10	53	24
11	84	64	4	7	52	29
12	93	68	14	16	42	41
13	79	63	9	4	53	44
14	72	54	12	5	47	34
15	92	75	14	18	86	71
16	84	91	21	19	46	41
17	94	91	17	15	51	56
18	152	153	31	31	81	50
19	106	109	16	10	60	34
20	138	158	58	49	142	110
21	76	62	15	13	95	77
22	96	117	25	23	78	48
23	68	75	18	18	69	56
24	57	70	15	7	23	28
25	129	152	62	60	238	192
26	34	64	13	21	32	41
27	55	64	14	22	69	64
28	64	73	10	18	39	38
29	31	34	9	7	21	16
30	153	157	60	51	229	196
31	16	18	10	10	65	56
32	38	38	10	12	52	34
33	35	22	9	8	41	48
34	19	12	7	3	16	8
35	131	100	35	39	222	208
36	23	18	8	3	34	24
37	28	25	8	8	46	27
38	24	16	6	7	24	28
39	10	10	5	1	18	16
40	146	68	55	50	229	202
41	14	7	5	6	46	42
42	20	11	4	2	39	20
43	4	7	7	3	30	28
44	9	4	4	2	17	9
45	64	51	30	24	167	122
46	9	5	4	—	32	14
47	9	5	4	3	40	18
48	10	10	9	2	20	15
49	7	4	2	—	15	7
50	69	37	49	51	187	131
51	7	4	1	2	72	34
52	10	3	4	4	33	23
53	4	3	6	4	48	25
54	2	3	3	1	15	9
55	27	16	31	22	168	102
56	5	5	6	2	27	10
57	7	1	5	3	31	17
58	12	1	4	4	21	18
59	3	1	—	2	9	5
60	75	34	53	31	245	194
61	4	—	9	4	60	35
62	11	3	4	2	28	14
63	7	—	5	1	29	23
64	6	4	3	—	6	2
65	30	16	25	13	188	137
66	3	1	4	1	27	14

TABLE I.—(*continued*).

Years completed at Death	Rome		Hispania and Lusitania		Africa	
	♂	♀	♂	♀	♂	♀
67	3	4	1	2	23	15
68	4	1	2	—	20	7
69	1	—	—	—	7	5
70	43	14	48	17	277	179
71	4	3	6	3	67	42
72	5	3	3	6	27	14
73	4	2	3	2	42	15
74	2	—	3	—	8	4
75	16	16	25	14	249	182
76	6	—	1	1	22	7
77	4	1	3	—	18	11
78	4	2	1	—	14	3
79	1	—	—	—	2	6
80	39	12	23	6	264	155
81	—	1	4	3	62	30
82	3	2	2	1	22	13
83	3	2	2	—	16	12
84	3	—	—	—	6	1
85	13	3	14	2	173	102
86	3	1	2	1	12	7
87	3	2	—	1	16	9
88	2	1	—	1	9	7
89	—	—	—	1	9	1
90	17	3	5	2	95	58
91	1	—	1	—	33	12
92	1	1	1	—	14	5
93	1	—	3	—	18	5
94	2	—	1	—	3	—
95	4	1	3	—	70	43
96	5	—	—	—	6	4
97	2	3	3	—	14	9
98	2	—	—	1	5	1
99	2	—	—	—	6	2
100	1	1	2	2	46	39
101	—	—	2	—	19	33
102	—	—	—	—	6	4
103	1	—	—	1	7	10
104	—	—	—	—	1	—
105	2	—	—	—	39	20
106	—	1	—	—	3	1
107	—	—	—	—	5	1
108	—	—	—	—	—	1
109	—	—	—	—	1	—
110	—	—	—	—	21	8
111	—	—	—	—	3	2
112	—	—	—	—	1	—
113	1	—	—	—	1	—
114	—	—	—	—	1	—
115	—	—	1	1	7	9
116	—	—	—	—	—	—
117	—	—	—	—	—	1
118	—	—	—	—	—	—
119	—	—	—	—	—	—
120	—	—	—	—	9	3
121	—	—	—	—	1	1
122	—	—	—	—	—	—
123	—	—	—	—	—	1
124	—	—	—	—	—	—
125	—	—	1	—	4	4
126	—	—	—	—	—	—
127	—	—	—	—	1	—
128	—	—	—	—	—	—
129	—	—	—	—	—	—
130	—	—	—	—	—	1
131	—	—	—	—	1	—
132	—	—	—	—	—	1
Totals	4575	3490	1111	885	6238	4459

TABLE II.

Age of Roman Women at date of Marriage.

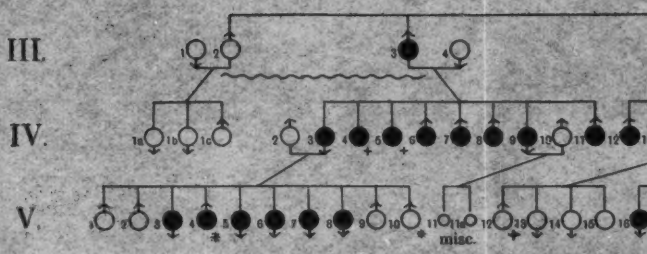
Age	Number of Women	Age	Number of Women	Age	Number of Women
7	1	*17*	1	*28*	1
10	3	*18*	4	*30*	1
12	7	*19*	2	*31*	1
13	6	*20*	6	*32*	1
14	6	*21*	2	*56*	1
15	8	*24*	1		
16	5	*25*	2		59

TABLE III.

Age of the Soldiers of the Roman Garrison on Entering the Army.

Age	Number of Soldiers	Age	Number of Soldiers	Age	Number of Soldiers
15	2	*24*	8	*33*	1
16	15	*25*	12	*38*	1
17	28	*26*	7	*43*	1
18	72	*27*	9	*45*	1
19	59	*28*	1	*47*	2
20	91	*29*	2	*52*	1
21	31	*30*	3		
22	29	*31*	2		400
23	18	*32*	4		

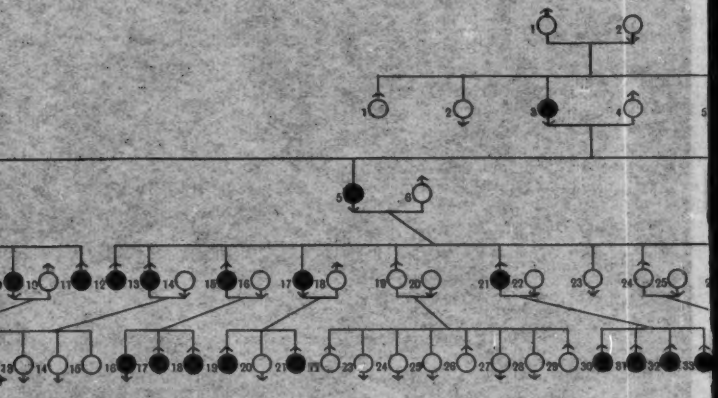
PEDIGR



* = Still-born.

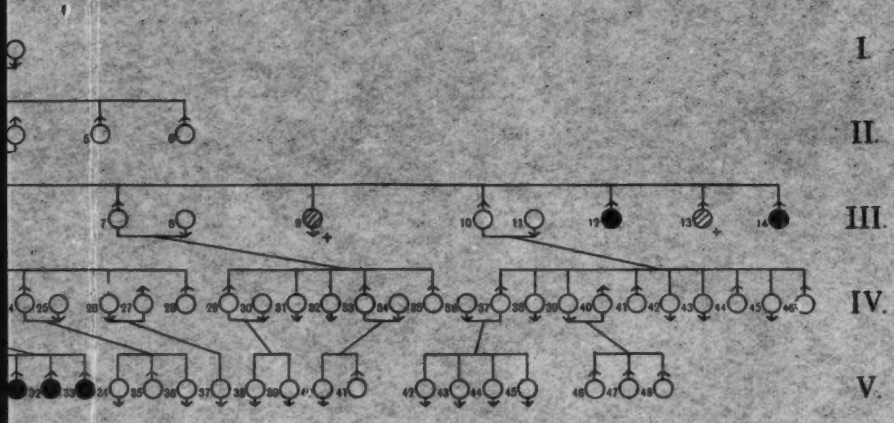
After this pedigree was engraved the Rector of N. wrote to the Editor

PEDIGREE OF THE *S.* FAMILY WITH HEREDITARY



ote to the Editor stating that he had found at last the entry of *W. S.* (III. 2) in the bu
of III. 2 and III. 3, expressed by the wavy line in the diagram, is

ITARY "LOBSTER CLAW."



+ = Died young.

) in the baptismal register, two years *later* than that of III. 3, so that doubt as to order of birth liagram, is now removed.

ON THE INHERITANCE OF THE DEFORMITY KNOWN AS SPLIT-FOOT OR LOBSTER-CLAW.

(SECOND PAPER.)

By GEORGE McMULLAN, M.D. and KARL PEARSON, F.R.S.

In 1908 Pearson discussed the pedigree of a certain Lobster-Claw or Split-Foot Family in this Journal*. Pearson's information was obtained from several members of the family, but his photographs and skiagrams were of one particular section of it. McMullan, unacquainted with Pearson's paper, read a paper on the same family before the Reading Pathological Society in 1910. He worked principally with a different section of the family and his photographs and skiagrams did not cover the same individuals as Pearson's. Hearing of the latter's paper, McMullan placed his material at the disposal of the Editor of this Journal and the present supplementary memoir is the result. During the five years that have intervened since the first paper several additions have been made by birth to the family; thus while Pearson dealt with 25 deformed individuals the present account contains 33†. Further, somewhat fuller particulars have been found of the two earliest generations. The order of birth of Generation III. and further the total number of brothers and sisters were given differently by different members of the family to Pearson and to McMullan. These discrepancies led Pearson to make some investigation into the church registers, but they disclosed a rather chaotic state of affairs. Some facts, however, resulted. *Ann J.* (II. 3) was married to *Francis S.* (II. 4), at N. in the Chilterns in 1837, both being unable to sign their names. It was supposed that III. 2, 3 and 5 were born before the *S.'s* migrated to W. The names of most of the other children in Generation III. are to be found at about the proper dates in the baptismal register of W. But not until the birth of *John S.* (III. 13), who must have died under two years of

* *Biometrika*, Vol. VI. p. 69, 1908.

† Besides six additional births of deformed children since the date of Pearson's record, IV. 9 has recently stated that her parents had two deformed children who died as infants, IV. 4 and IV. 5. The statement is now confirmed by IV. 3.

age,—for his brother born in 1866 is also *John S.*—do the names *Francis* and *Ann S.* reappear. The births of *William S.* (III. 2), *James S.* (III. 3), and *Elizabeth S.* (III. 5) are fixed by the registers of N., but another *James S.*, and an *Eliza Ann S.*, *Charles S.* (III. 7), *Emma S.* (III. 9) and *Thomas S.* (III. 10) are attributed in the registers of W. in four cases to *Thomas* and *Frances S.* and in one case to *William* and *Ann S.*! There was thus very great carelessness in the preparation of the baptismal register, or our illiterate couple frequently changed their names, or there were other families of the same surname and with children with the same Christian names in the parish, although there is no other trace now of their former existence. Ultimately, therefore, we are again thrown back on the statements made by the two survivors of Generation III., who, it may be noted, did not give their parents names correctly, or on those of the granddaughter IV. 3, who has, after an interval of five years, given almost the same account of Generation III. as she did in 1908, and on both occasions referred to III. 2, III. 9 and III. 13, who seem substantiated by the registers, although they were not referred to by III. 7 and III. 14. Probably Generation III. is now in fairly correct order, although it is possible that two further children—who must have died young—namely, another *John* (1848) and another *Thomas* (1852), really belonged to this pair, who were married in 1837 and were still having children in 1866. Of course it is not possible to ascertain whether such children or III. 9 and 13 really were deformed or not, although IV. 3 asserted that III. 9 was normal, presumably on the authority of her father, III. 3.

In the following account a pedigree number with P. P. affixed refers to the index number of the corresponding individual in Pearson's Pedigree in the earlier paper. The accounts given there are not reproduced unless there are additions to be made to them.

Account of Pedigree.

I. 1 and I. 2 are now given and given as normal, because of the following legend, recently unearthed, which attributes the origin of the deformity to "maternal impression."

I. 2 the great-great-grandmother of the latest generation being pregnant committed a theft; when charged with the offence she denied it and further invoked her Creator to let her child when born have no fingers to steal with, should she be guilty. In due course the infant was born without fingers or toes and the woman confessed to the theft lest a greater evil should befall her. All which account is very picturesque but somewhat unconvincing. As far as one can gather, the woman was well advanced in pregnancy; and no explanation is suggested of the process by which the digits were separated, nor of their ultimate fate. Perhaps the appeal is to the miraculous rather than to a maternal impression. But the legend is so far of interest that it seems unlikely that the mother or father of II. 3 were deformed, otherwise, there would have been no necessity to account for the appearance of the deformity in II. 3. Pearson gave

II. 3 (P. P. I. 2) one brother and one sister (P. P. I. 3 and 4), but was unable to find any real evidence as to their condition. McMullan's informants provide no less than three brothers and one sister, II. 1, 5 and 6 and II. 2 respectively, all stated to be normal. But no evidence is forthcoming as to their names, place of origin, residence or descendants. *Ann J.* (II. 3) is reported to have been a servant in a farmhouse at N., and the legend suggests that her mother was possibly of the same class as some of her more recent descendants, which have included tramps, wandering labourers and paupers. It seems almost impossible therefore to trace any of this *J.*-family now; some years ago Pearson made, without result, inquiries of residents and medical men in the neighbourhood of N., both as to the family and as to the existence of any similar deformity in the district. No stress ought to be laid on the numbers in Generation II., they are probably not exact. Of *Francis S.*, II. 4 (P. P. I. 1), we know nothing beyond his name and the fact that he could not write it. There is no evidence whatever to suppose him in any way of the same stock as II. 3*. It is clear that II. 3 could not, in Mendelian language, have been either a pure recessive (*RR*) or a pure dominant (*DD*). In the former case she would have had no affected children, in the latter case all affected children. She must be looked upon as an impure dominant (*DR*). Thus every normal in the pedigree must be looked upon as an (*RR*), and consequently since every mate is a normal, all the affected can only be (*DR*)'s.

In Generation III., we have at least nine children born to *Ann J.* (*Mrs S.*), perhaps there may have been one or two more who died young and without possibility of any record of deformity surviving. Of these nine, four were affected, three are known to have been normal, one is reported normal (III. 9), and the nature of the other (III. 13) is certainly unknown. This gives a quite reasonable Mendelian 50 °/₀.

In Generations IV. and V., where we know the individuals much more accurately, there are eight matings of affected (*DR*) with normal (*RR*). Of these that of IV. 9 and 10 contributes nothing as there have been only two early miscarriages. The remaining seven matings have so far produced 41 offspring, of whom 28 have been affected, nearly two-thirds. The ratio is thus nearly 2 : 1 and not 1 : 1. The odds against such an excess as 28 to 13 are about 100 to 1, and they tell very heavily against any simple Mendelian theory applying to this deformity.

Thus far the normal members of the stock *when mated with outside normals* have bred only normals. This is no convincing argument for Mendelian theory, because in no case has an intra-stirp normal been mated either with another intra-stirp normal or with an abnormal. Both such matings would have to be considered before we could assume that an intra-stirp normal is as free from taint as an extra-stirp normal. Further the fact that three out of the seven matings have given nothing but deformed offspring is most remarkable and almost impossible on any purely Mendelian theory. If III. 3, IV. 15 and IV. 21 had been pure dominants,

* IV. 3 distinctly states that there was no consanguinity.

(*DD*)'s instead of (*DR*)'s, this result would have occurred. While if III. 5, IV. 3, IV. 13, IV. 17 had been (*DR*)'s their 26 offspring would have given 13 affected and 13 unaffected as they actually do. It appears fairly clear that III. 3, IV. 15 and IV. 21 were in some manner far more prepotently affected with the taint than the other four. But even if we examine the other four, IV. 3 and IV. 13 seem to be affected in quite different degrees; thus not only on the average, but individually, the seven families are very improbable on the Mendelian hypothesis; they suggest a graded intensity of taint in the germ-plasm of the different affected members of the stock. But the moment such relative prepotency of the individual is admitted, Mendelian segregation in definite ratios falls to the ground. A still more difficult point is the definition of what a Mendelian "unit" character is in such a case as the present. McMullan's fuller descriptions completely confirm the very great variation in the deformity, which as Pearson pointed out in 1908 could affect any number from 10 to 60 bones. But it is not only the bones that are affected. The usual type is a claw-like foot or hand, the digit or digits remaining being bent round at an angle to the remainder of the hand or foot. This is very manifest in the bulk of the skiagrams and photographs of the present and the earlier paper. But the case of V. 8, born since the earlier paper, and several photographs in this paper show that a single *straight* digit is a possibility.

Ann J. II. 3 (P. P. I. 2). *Mrs Francis S.* Married to *Francis S.* at N., April 15, 1837. There is nothing to add to the description of the deformity given in this case by Pearson.

James S. III. 3 (P. P. II. 6). Born March 4, 1838. Both hands and feet deformed. Pearson's and McMullan's informants agree as to feet both presenting 1st and 5th toes only. But Pearson's informant (IV. 3) says there were two fingers on right hand, one finger and thumb on left; while McMullan's informant says there was only the fourth finger on both hands. The difference between the right and left hands stated positively by the eldest daughter must, we think, stand.

William S. III. 2 (P. P. II. 2). Born February 10, 1840. Normal. Year of death not found. Three normal children IV. 1 *a*—*c* (P. P. III. 1—3).

Jane R. III. 4, a native of C., was quite unrelated to her husband, III. 3.

Elizabeth S., afterwards *Mrs Wh.* III. 5 (P. P. II. 3), dead. Born April 23, 1842. Both McMullan's and Pearson's informants agree that she had normal hands; the former reports both feet as having only their 5th toes, the latter as having the 1st and 5th toes.

—— *Wh.* III. 6 (P. P. II. 4). Husband of III. 5; he was unrelated to his wife, but is now reported to have had a deformed foot, quite different from those of his wife, and probably to judge by the description a club-foot.

George S. III. 12 (P. P. II. 10) (dead). Date and locus of birth? no information beyond that already given by Pearson that both hands and feet were deformed.

John S. III. 14 (P. P. II. 3), seen by Pearson's field worker and again by McMullan *. Born, 1866. Scavenger, unmarried; both hands and feet affected.

Feet. Examination refused, but said he had the 5th toe only present on each.

* Bones present and those absent in this as in other cases made out by palpation. Such a method leaves something to be desired, but many of the affected persons feel their affliction keenly and are not willing to have it further investigated even if X-ray apparatus were available, which it is not in country districts.

Hands. Carpus apparently normal on both right and left; metacarpals: 1st, 3rd, 4th and 5th present on right hand, 2nd absent or rudimentary; 3rd, 4th and 5th present on left hand; 4th finger three phalanges present on both hands. Thumb on right only, rudimentary, one phalanx.

—— *S. Mrs R.*, IV. 3 (P. P. III. 21). McMullan's informant gave no additional information, and the skiagrams in the first paper fully describe the case.

IV. 4 and 5. Two children, sex unstated, reported recently by IV. 9, said to have died as infants and to have been deformed.

George S. IV. 6 (P. P. III. 22). Dead, unmarried. Hands and feet deformed; deformities irregular, described by Pearson's informant; they involve polydactyly: see *loc. cit.*

Richard S. IV. 7 (P. P. III. 23). Inmate of workhouse, unmarried. Hands and feet deformed.

Hands	*Right*	*Left*
Carpus.	Trapezium probably absent.	Normal.
Metacarpals.	2nd, 3rd, 4th and 5th present.	1st, 2nd, 3rd, 4th and 5th present, 1st rudimentary.
Phalanges.	Mid-finger, one rudimentary phalanx. 4th finger, three phalanges.	First finger, one rudimentary phalanx. Ring finger, one fairly well-developed phalanx. Little finger, three phalanges.

Feet. Both show the same deformity.

Tarsus. Probably middle and external cuneiform bones absent.

Metatarsals. 1st and 5th only present.

Phalanges. 1st toe, two fused phalanges. 5th toe, three fused phalanges (i.e. no moveable joints are demonstrable). A web of skin is present between the two digits.

For photographs of hands and feet: see Plate XXVII, Figs. (xv) and (xvi).

Francis S. IV. 8 (P. P. III. 26). Farm labourer. *Hands* said to have one finger only, the 4th, present.

Feet said to resemble last case.

Annie Eliza S. (*Mrs F.*). IV. 9 (P. P. III. 24). Married, no living children; has had two abortions at the 4th month (V. 11—12). Has both hands and feet deformed.

Hands	*Right*	*Left*
Carpus.	Normal.	Normal.
Metacarpals.	Normal.	Normal.
Digits.	Thumb, one very rudimentary bone.	Thumb, short otherwise normal.
	Index finger absent.	1st finger, one small rudimentary phalanx.
	Mid and ring fingers united, one nail only present, and bones partially fused to each finger, three phalanges.	Mid finger, very long, three phalanges.
		Ring finger dichotomous at 2nd joint.
	4th finger normal.	4th finger normal.

Feet. Both show a similar deformity. Presence of middle and external cuneiform bones doubtful. 1st and 5th metatarsals only present. Phalanges, normal in number, but ankylosed.

For photograph of hands: see Plate XXV, Fig. (vi); and for that of feet: see Plate XXVII, Fig. (xviii).

Herbert S. IV. 11 (P. P. III. 27). Farm labourer, unmarried. Hands and feet deformed.

Hands	*Right*	*Left*
Carpus.	Apparently normal.	Apparently normal.
Metacarpals.	1st, 3rd, 4th and 5th present.	1st, 2nd (probably present but small and rudimentary), 3rd, 4th and 5th fairly well developed.
Digits.	Thumb, rudimentary, one small phalanx. Ring and 5th fingers united by thick fleshy web. Three phalanges to each.	Thumb rudimentary, one small bone. Middle and ring fingers fused, one nail. Three phalanges to each. 5th finger normal.

Feet. Show a deformity similar to *Eliza S.* (IV. 9).

For photographs of hands and feet: see Plate XXVI, Figs. (ix) and (x).

Wm. Wh. IV. 12 (P. P. III. 4). Dead, unmarried. Hands and feet said to have been deformed. Said to have had only the little finger and 5th toe present.

Alfred Wh. IV. 13 (P. P. III. 5). Married. (Four normal children, V. 12—15.) Hands and feet said to be deformed. Hands said to be broad with 5th digit present on each and a thumb on right hand. Feet to have 5th toe only present.

Chas. Wh. IV. 15 (P. P. III. 7). Married, whereabouts unknown (has three deformed children). Hands and feet in this case said to be affected; in what manner not specified.

Eliza Wh. (*Mrs Sm.*). IV. 17 (P. P. III. 9). Recently an inmate of Claybury Asylum suffering from confusional insanity. Discharged recovered. Hands and feet deformed: has had three children, two male deformed and one female normal. One of the male children and the female child are dead. Stated when in asylum that she had had a fourth child with deformed hands and feet when sixteen years old, but statement doubtful.

Hands	*Right*	*Left*
Carpus.	Normal.	All the bones appear to be present though the trapezium and trapezoid are not well developed.
Metacarpals.	1st very rudimentary. 2nd badly developed. 3rd, 4th and 5th normal.	3rd present, rudimentary. 4th and 5th well developed but showing a measure of deformity.
Digits.	One, the 5th, alone present, shows ankylosis.	A small bone lies between the heads of the 4th and 5th metacarpals, possibly a rudimentary digit. The 5th digit present and badly developed.

Feet. Tarsus. In the case of the feet the deformity is difficult to determine, both however show either absence or very imperfect development of the middle and external cuneiform bones.

Metatarsals. The 1st and 5th alone are present in the left foot while the right shows these two bones, and also a rudimentary 4th metatarsal.

Digits. 1st and 5th alone present, the number of bones in each is normal, but much deformity is shown, i.e. ankylosis, dislocations, etc.

Skiagraphs, hands and feet, Plates XXIII—XXIV; photograph, Plate XXV, Fig. (v).

Our best thanks are due to Dr Robert Jones of Claybury Asylum for acquainting us with the facts regarding this case, and providing a photograph and skiagraphs of the deformities.

G. Wh. IV. 19 (P. P. III. 11). Normal, married, with eight normal children, V. 22—29 (P. P. IV. 8—14, and one additional birth).

Thomas Wh. IV. 21 (P. P. III. 16). Green keeper on golf course. Married, four children all showing deformity.

Right and Left.

Hands.	Carpus.	Trapezium presence doubtful. Trapezoid probably not fully developed on left hand.
	Metacarpals.	Three inner bones alone present.
	Digits.	4th finger only present, very much curved, three phalanges.
Feet.	Tarsus.	Presence of middle and external cuneiforms doubtful.
	Metatarsals.	5th alone present. A small hard mass is present lying over internal cuneiform bone, possibly a rudimentary 1st metatarsal.
	Digits.	5th alone present, much curved, three phalanges.

For photographs of hands and feet: see Plate XXVII, Figs. (xiii) and (xiv).

Annie Wh. IV. 23 (P. P. III. 13). Normal.

Henry Wh. IV. 24 (P. P. III. 16). Dead, normal; three normal children, V. 34—36.

Clara Wh. IV. 26 (P. P. III. 18). Dead, normal; one normal child, V. 37.

John Wh. IV. 28 (P. P. III. 19). Normal.

We now come to *Mrs R.'s* family:

V. 1 and 2 (P. P. IV. 17, 18). Two normal sons.

V. 9, born since the first paper was written, also a normal boy; V. 10, ditto, but stillborn.

The remainder of the family are deformed. All have the little finger only on the hands, but as Pearson's Plate IX and skiagrams in the earlier paper show, this may mean very different bones missing even in the two hands of the same individual.

V. 3=P. P. IV. 19. V. 4=P. P. IV. 20. V. 5=P. P. IV. 21. V. 6=P. P. IV. 22. V. 7=P. P. IV. 23. Accounts will be found in Pearson's paper, detailed in the cases of V. 5 and V. 7.

V. 8=P. P. IV. 24, the "expected birth" of the first paper recorded in a footnote (p. 74) as a girl deformed in hands and feet. She differs from the other members of this branch of the family in having a single (little) finger straight on the left hand; but this single finger is crooked on the right; she has two toes (big and little) on each foot, both "clawed" round, being thus like her mother, and differing from her sister, V. 3.

Eliza Wh. V. 16 (P. P. IV. 4). Hands and feet deformed.

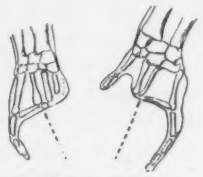
Hands	*Right*	*Left*
Carpus.	Scaphoid presence doubtful. Trapezium probably absent.	Scaphoid and trapezium probably absent.
Metacarpals.	2nd, 3rd, 4th and 5th present.	2nd (rudimentary), 3rd, 4th and 5th.
Digits.	Ring and little fingers closely united by fleshy web, double nail. Three bones in each.	Ring and little fingers closely united by a thick fleshy web, double nail. Three phalanges in each finger. Rudimentary middle finger, one small phalanx.

Feet. Same deformity in each foot.

Tarsus.	Presence of the middle and 1st cuneiform bones doubtful.
Metatarsals.	1st and 5th only present.
Digits.	1st and 5th alone present, much curved, resembling a crab's claws, normal number of bones in each digit, but joints are ankylosed.

Fred. W. V. 17 (P. P. IV. 5). Hands and feet deformed. The deformity of the hands is difficult to determine (see diagram), but probably the rigid bar of bone felt running along the free

border of the hand is due to a displaced phalanx, or to two phalanges fused and displaced*. The hands as in the majority of cases show poor muscular development; the five metacarpals are palpable on the left hand.



Rigid bars of bone.

Hands	*Right*	*Left*
Carpus.	Apparently normal.	Normal.
Metacarpals.	1st absent, 2nd rudimentary, 3rd rudimentary, but larger. 4th and 5th of normal length.	Normal but the middle three are deflected towards the thumb.
Phalanges.	In both hands a bone is felt lying between the heads of 4th and 5th metacarpals, probably a phalanx of ring finger: see diagram above.	
	5th digit shows three phalanges.	1st digit rudimentary. 5th digit, three phalanges.

The feet show the same deformity as those of *Eliza Wh.*, his sister.

For photograph of hands: see Plate XXVII, Fig. (xvii), to right.

Henry Wh. V. 18 (P. P. IV. 6). Hands and feet defective. Hands have one digit only on each; feet resemble those of his sister, *Eliza Wh.*, V. 16.

Hands, symmetrical.

Carpus.	Trapezium and trapezoid bones probably absent in both hands.
Metacarpals.	3rd metacarpal probably present but very imperfectly developed. 4th metacarpal better developed. 5th metacarpal normal.
Digits.	5th only present on each hand, much curved, and joints partially ankylosed.

For photograph of hands: see Plate XXVII, Fig. (xvii), to left.

William Wh. or *Sm.* V. 19 (P. P. IV. 7). Dead. Hands said to have one finger only present. Feet normal.

Alfred Wh. or *Sm.* V. 21 (P. P. unborn). At present in one of Dr Barnardo's homes. One finger only on each hand, the 4th, well developed. *Feet.* The outer digits alone present, though feet appear well developed save for the absence of the toes.

We are indebted to Dr C. T. Ewart of Claybury Asylum for the facts and photograph of this case.

For photograph: see Plate XXV, Fig. (vii).

William Wh. V. 30 (P. P. IV. 15). Hands and feet deformed.

Hands. *Right* and *left* are symmetrical.

Carpus.	Trapezium probably absent.
Metacarpals.	The inner three alone present.
Digits.	Little finger only present and has three phalanges with freely moveable joints.

* This case is of peculiar interest as showing in the *S.*-family the occurrence of the same "bridge" type or "cross-bone" type that Lewis and Embleton have illustrated by skiagrams in the *G.*-family; see *Biometrika*, Vol. VI. p. 41 and plates.

Feet. Also symmetrical.

Tarsus.	The external and middle cuneiform bones are probably absent.
Metatarsals.	5th alone present.
Digits.	A small and very much curved little toe only is present; it probably has the normal number of bones in it.

For photograph of hands and feet: see Plate XXVI, Fig. (xi).

Thos. W. Wh. V. 31 (P. P., then unborn). Hands resemble those of his brother (V. 30) in every respect: but have more marked grooves between metacarpal heads.

Feet	*Right*	*Left*
Tarsus.	The presence of the middle and external cuneiform bones is doubtful.	Apparently normal.
Metatarsals.	5th alone present. 1st present, rudimentary.	Probably a rudimentary 1st. 5th present.
Digits.	5th alone present and curved. Small mass of fibrous tissue overlies the rudimentary 1st metatarsal.	5th normal in number of bones, but curved.

This child is only five years of age and it is difficult to say with any degree of certainty which bones are present and which absent in the case of the carpus, tarsus and the metacarpal and metatarsal bones. This is true also of the following case.

For photograph of hands and part of feet: see Plate XXVI, Fig. (xii).

R. Wh. V. 32 (P. P., then unborn). Hands and feet deformed.

The hands are symmetrical and probably have the trapezium, at least, absent. Either the inner two or three metacarpal bones are present, but are badly developed, except the innermost. One digit, the little finger, alone is present, and has the usual three bones; it is very much curved.

The feet are asymmetrical.

	Right	*Left*
Tarsus.	Possibly normal, though the cuneiform bones are not palpable.	
Metatarsals.	1st rudimentary, 5th normal.	1st and 5th present.
Phalanges.	Three bones in 5th digit.	The first toe is long, and apparently composed of two bones. The little toe is as long as a child's middle finger, perfectly straight and without a nail. Three bones present.

For photograph of hands and feet: see Plate XXV, Fig. (viii). The photo does not give a proper idea of left foot which looks more as in diagram.

— *Wh.* V. 33 (P. P., then unborn). An infant, three months old. Hands and feet deformed, the deformity of the hands resembling those in V. 32.

The feet both show a well-developed little toe, and a mal-developed great toe.

The additional information now obtained is of much interest. We can assert:

(i) That our increased knowledge has not shown the deformity to give any closer approach to Mendelian inheritance—on the contrary the disproportionate number of abnormals has increased.

(ii) That the experience of the last five years further emphasises the importance of legislative interference with the propagation of deformity.

Pearson in 1908 laid stress on the wide variation found in the types of hand and foot, and remarked that all Lewis and Embleton's types from the *G.*-family with the exception of the "cross-bones" had been found in the *S.*-family; but he suggested that this might also be revealed if the whole family were skiagraphed. McMullan has now shown that this type actually exists.

A careful comparison of the present pedigree with the former one will show that, if additional births be put on one side, the chief changes are in the orders of birth in the earlier generations. We cannot lay much stress even now on these orders. In the class with which we have here to deal, the members frequently seem uncertain of their own ages—and are therefore ignorant of their brothers' and sisters' ages and their order of birth. When we find that they do not know their own mother's Christian name correctly, we need not be surprised that they contradict each other's statements as to the relative ages or even as to the numbers of their brothers and sisters. This especially will be the case in people of this class when the youngest is born 25 to 28 years later than the eldest. Unfortunately the Church baptismal registers appear equally chaotic; they make no pretence to identify father and mother by the same names in two successive years! On the whole there is a reasonable agreement in the two accounts. Those who have studied such families as those in the *G.** and *S.*-pedigrees of Lobster-claw, must earnestly wish for some immediate step to be taken to restrict the propagation of the physically defective; it is no less urgent than the restriction of the propagation of the mentally defective.

* We have further evidence that in the *G.*-family there has also been a considerable number of births of deformed individuals in the last five years, and a similar experience has arisen in the case of a number of pedigrees of hereditary deformity recently brought up to date by the Eugenics Laboratory staff.

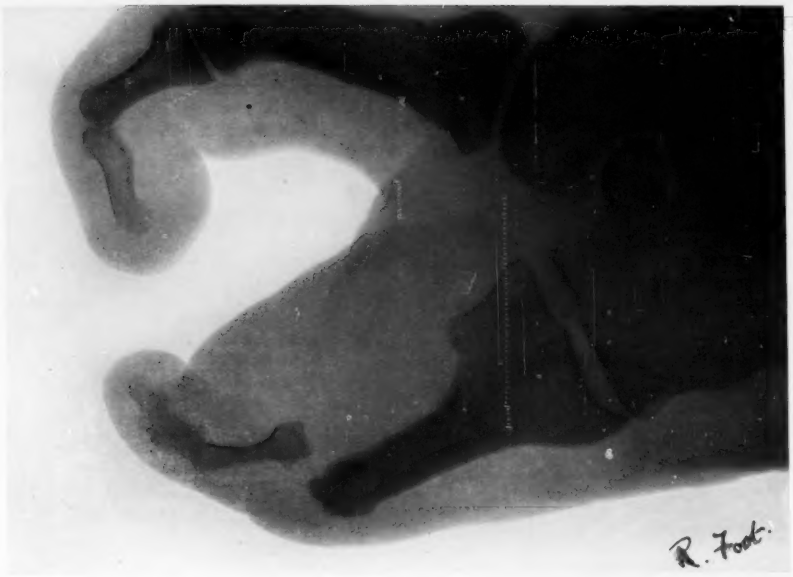


Fig. (i). *E. Sm.* Pedigree IV. 17. Right Foot. (See Plate XXV, Fig. (v).)

Fig. (ii). *E. Sm.* Pedigree IV. 17. Left Foot.

"LOBSTER CLAW" FAMILY.

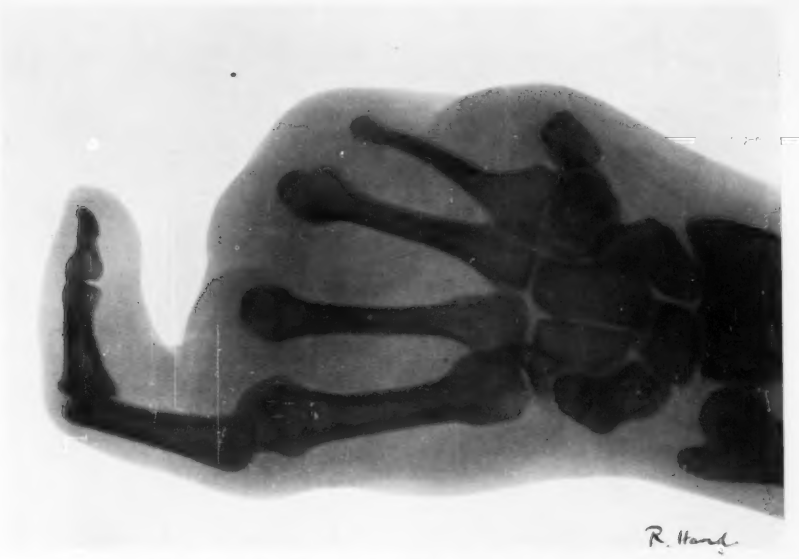


Fig. (iii). *E. Sm.* Pedigree IV. 17. Right Hand. (See Plate XXV, Fig. (v).)

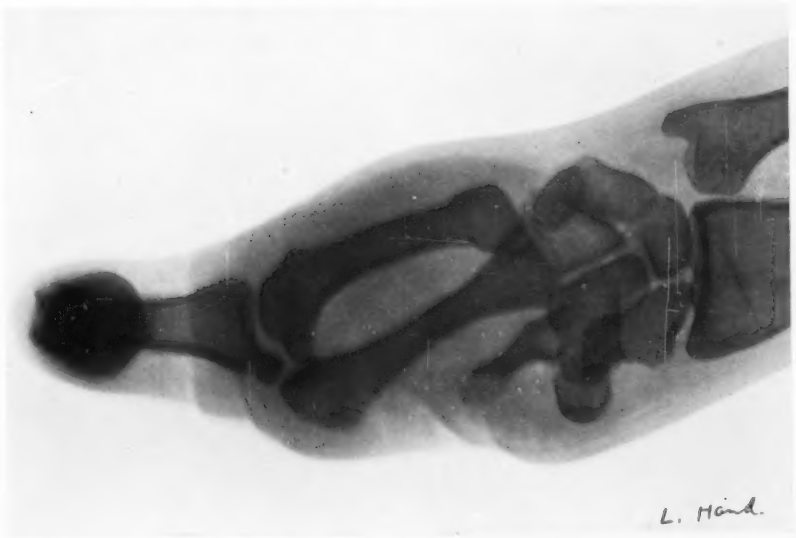


Fig. (iv). *E. Sm.* Pedigree IV. 17. Left Hand.

"LOBSTER CLAW" FAMILY.

Fig. (v). *E. Sm.* Pedigree IV. 17. Hands and Feet. (See Plates XXIII—XXIV.)

Fig. (vi). *A. E. F.* Pedigree IV. 9. Hands. (See Plate XXVII, Fig. (xviii).)

Fig. (vii). *A. Wh.* Pedigree V. 21. Right Hand, and Feet.

Fig. (viii). *R. Wh.* Pedigree V. 32. Hands and Feet.

"LOBSTER CLAW" FAMILY.

Fig. (v). *E. Sm.* Pedigree IV. 17. Hands and Feet. (See Plates XXIII—XXIV.)

Fig. (vi). *A. E. F.* Pedigree IV. 9. Hands. (See Plate XXVII, Fig. (xviii).)

Fig. (vii). *A. Wh.* Pedigree V. 21. Right Hand, and Feet.

Fig. (viii). *R. Wh.* Pedigree V. 32. Hands and Feet.

"LOBSTER CLAW" FAMILY.

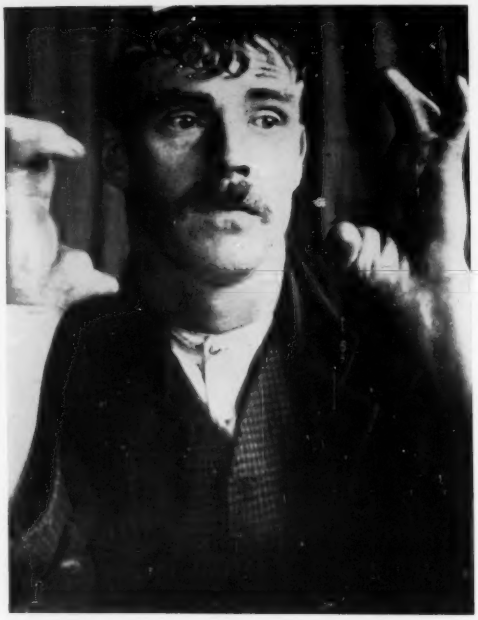


Fig. (ix). *H. S.* Pedigree IV. 11. Hands.

Fig. (x). *H. S.* Pedigree IV. 11. Feet.

Fig. (xi). *W. Wh.* Pedigree V. 30. Hands and Feet.

Fig. (xii). *T. W. Wh.* Pedigree V. 31. Hands and Part of Feet.

"LOBSTER CLAW" FAMILY.

Fig. (xiii). *T. Wh.* Pedigree IV. 21. Hands.

Fig. (xiv). *T. Wh.* Pedigree IV. 21. Feet.

Fig. (xv). *R. S.* Pedigree IV. 7. Hands.

Fig. (xvi). *R. S.* Pedigree IV. 7. Feet.

Fig. (xvii). *H. Wh.* Pedigree V. 18. *F. W.* Pedigree V. 17. Hands.

Fig. (xviii). *A. E. F.* Pedigree IV. 9. Feet. (See Plate XXV, Fig. (vi).)

"LOBSTER CLAW" FAMILY.

A STUDY OF THE NASAL BRIDGE IN THE ANTHROPOID APES AND ITS RELATIONSHIP TO THE NASAL BRIDGE IN MAN.

By KATHLEEN V. RYLEY, Crewdson-Benington Student in Craniometry AND JULIA BELL, M.A., assisted by KARL PEARSON, F.R.S.

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(1) *Introductory.*

The measurements on which the following paper is based were taken by Kathleen V. Ryley, in part at the Museum of the Royal College of Surgeons by the kindness of Professor Arthur Keith; in part at the British Museum (Natural History), where we have especially to thank Mr W. P. Pycraft; in part at the Cambridge Anatomical Museum and in the private collection of Dr Duckworth, whom we have heartily to thank for his courteous and ready aid; in part at the Oxford Museum by the kindness of Professor Bourne. Lastly we owe the possibility of measuring a few specimens to Professors Thane and Hill of University College, London, who readily placed their material at our disposal. We have further to express our indebtedness to Professor Thane and to Dr Derry for aid in a variety of other ways. Only by the great help received from all these authorities would

it have been possible to bring together even the slender numbers now dealt with, and a very full sense of our obligations to these gentlemen must here be expressed.

In a recent paper entitled "A Study of the Negro Skull" (*Biometrika*, Vol. VIII. pp. 315—320) a special study was made of the nasal bridge in the Congo and Gaboon crania and the results compared with measurements on Egyptian and English series. There resulted values so suggestive that a wider study was promised, and that promise is to some extent fulfilled in the present paper.

In the former paper it will be remembered that the chord from dacryon to dacryon (*DC*) was measured—the mesodacryal chord—and the minimum arc from dacryon to dacryon (*DA*)—the mesodacryal arc. The ratio 100 (arc – chord)/chord was termed the mesodacryal index β. If on the other hand we measure the subtense of the minimum arc (*DS*) and take the index 100 subtense/chord, we obtain a second mesodacryal index, which we will term here the mesodacryal index α. As α cannot be found without a special instrument, or a special construction, an attempt was made to determine the second mesodacryal index α from the first β by the hypothesis that in man the bridge of the nose may be sufficiently closely represented by a catenary, which seemed a fairly justifiable assumption in this case. The index thus indirectly found will be termed in this paper the mesodacryal index α'. Tables to determine α' from β calculated by one of us (Julia Bell) were published in the same number of *Biometrika*, pp. 338—9, as the paper on the negro skull. An extension of these Tables due to H. E. Soper, rendered necessary when we deal with apes, will be found in the footnote on p. 401 of the present paper. Meanwhile our attention was drawn by Professor G. D. Thane to Mérejkowsky's pioneer work of 1882 on the nasal bones. He measured the shortest horizontal chord from nasal suture to nasal suture (*SC*) and the minimum subtense (*SS*) and took the index 100 *SS*/*SC*, which we have ventured to term the *Simotic Index, S*. There is little doubt that this index is of a more simple anatomic character, as being only concerned with the nasal bones, than the mesodacryal indices. But it is by no means so marked a physiognomic feature in the living as the mesodacryal index. It has further to be obtained by aid of a special instrument—in our case a modified Mérejkowsky instrument,—which may be termed the simometer. This simometer may also be used to test the relationship between observed α and calculated α'.

In the present investigation α, β, S have been measured and α' calculated for Gorilla, Chimpanzee, Gibbon and Orang. But in the case of the latter ape it was found possible to measure the simotic index in only a few cases,—the index taking frequently the form of the ratio of two almost vanishing quantities*. In

* There were three cases in which the simotic chord was recorded among the Orang-utans. In two males it was 5·7 and 5·8 mm. In both these cases the subtense was zero, for the bones were practically flat; thus the simotic index was zero. In the third case, a female, the simotic chord was 7·0 mm. and the subtense 1·2 mm. and therefore the simotic index was 17·1. There were a few further cases in which the chord only was measurable. Thus on the basis of such isolated cases we should have to place the Orang-utan below the Chimpanzee, and both of course below the Negroes.

the Orang the nasal bones are fused into a narrow flat strip from 5 to 6 mm. wide, sometimes there is only a thread at the nasal bridge or the nasals are entirely absent. In some cases the maxillary bones stand out forming a ledge which overhangs the region of the dacryon and extends beyond it, thus making it very difficult to measure with Mérejkowsky's instrument. Initially we excluded entirely from our measurements the Gibbon, but notwithstanding the difficulties of including this ape, it afterwards appeared to us that it might be worth while to indicate the results in rough numbers. The difficulties partly arise from the fact that a large proportion of the Gibbon crania available are without any statement as to sex and we did not feel that an attempt at sexing would be really profitable, as the total numbers were not large enough to give double series. Further we are compelled to distinguish between *Hylobates* and *Symphalangus*, and even of the former with the sparse data as to locus usually provided, it is impossible to assert that we are dealing with anything like a homogeneous race. Thus we found ourselves ultimately with only 25 cases—♂ + ♀ + ♁ —*Hylobates*—indeed only 16 for the simotic characters, and 9 cases—♂ + ♀ + ♁ —*Symphalangus*—with merely six for the simotic characters. Our results in this case can therefore only be rough indications of the racial characters of the nose of these apes. Our Museums have yet to learn that for comparative study we want at least 50 to 100 crania of each sex drawn from definite districts. To compare with those of the apes the corresponding indices were measured in a number of human races selected in order to contrast the values, if possible, with those of the anthropoid apes of the same continent. A few other human races are taken to indicate general relationships. The Hindoo, Egyptian and English crania used are at University College either in the Biometric Laboratory or in the Department of Anatomy; the Asiatic skulls and the Congo skulls are at the Royal College of Surgeons; the Gaboon skulls at the British Museum of Natural History. The nasal features of the latter as well as of the English and Egyptian crania had already been discussed in Dr Crewdson-Benington's paper referred to above.

(2) *Reliability of Measurements.*

The first point to be considered is the degree of reliability in the measurements made, and here we must again emphasise the difficulty of accuracy. Not only do the quantities measured differ by their extreme smallness from the customary cranial measurements, but the points for measurement and the instrument for measurement are by no means all that could be desired. When a small quantity has to be measured, an error of reading which would have no importance in the case of either head breadth or head length, the cephalic index being in question, becomes of very great significance in the case of the simotic or even the mesodacryal indices. Further in the handling of Mérejkowsky's instrument, there is much play for personal equation, and only after long practise will the recorder settle down into a process, which repeats within reasonable limits the values of the indices previously determined. In the next place for our present purposes only small series of crania were as a rule available, e.g. 20 to 40 of either

sex of each ape, 10 to 40 of the various Asiatic races. Considering the smallness of these numbers, it did not appear needful, in view of the labour involved, to measure more than 50 of each sex of the English (Whitechapel) and Egyptian (XXVI—XXX dynasties) crania of which far larger numbers were at hand.

Further in such small series the question of sexing becomes of considerable influence. With a large series of crania of one type, we sex on our knowledge of that series itself. But in short series one is apt to sex by *a priori* impressions of sex in other races, because we have not before us wide enough material to appreciate sex differences within the race itself.

We propose to illustrate first the order of the differences which may arise from these sources, and we will deal first with sexing. Owing to the courtesy of Dr Derry we were able to test this point on 35 Nubian crania in his possession. They were independently sexed by Professor G. D. Thane and by Dr Derry himself*. The nasal measurements were taken and the mean values of the indices calculated. The following values were obtained, where we have added for comparative purposes those of other negro series:

TABLE I.

	m_a		$m_{a'}$		m_β		m_S	
	♂	♀	♂	♀	♂	♀	♂	♀
Nubians: Professor Thane ...	48·0	40·9	49·7	43·6	49·6	40·0	34·5	23·4
„ Dr Derry	48·9	39·7	51·0	42·1	51·6	37·7	33·7	23·5
Gaboon: 1864	42·9	44·0	43·6	44·9	40·0	42·0	30·9	27·7
„ 1880	42·9	44·1	44·8	45·1	41·9	42·3	29·0	22·9
Congo	39·1	37·2	40·5	38·6	35·5	32·6	25·6	25·7
"Nègres": Mérejkowsky ...	—	—	—	—	—	—	25·6	

It will be seen that for short series the personal equation of sexing makes 1 to 2 points difference in the indices, but that in two series of the same race—Gaboon, 1864 and 1880,—differences of this order may occur at least in the simotic index. If we compare Mérejkowsky's value for the simotic index with ours, we see that there would be excellent agreement if his somewhat vague "Nègres" were from the Congo district. But we lay no stress on this agreement because we believe that Mérejkowsky tends almost invariably to get a higher simotic index than we do. This is illustrated in Table II.

Of course there are but few races common to both series and in Mérejkowsky's series as in ours the numbers dealt with are miserably small, but still cases where

* Before discussion there were four crania in a total of 35 on which there was difference of opinion, say 11 per cent., and we have used the original determinations, putting as usual ?♂ and ?♀ with the ♂'s and ♀'s respectively.

we can compare and the general appearance of the Table are both against the view that the differences are wholly racial. We believe them to be largely due to personal equation in taking a delicate measurement with a not very reliable instrument, and consider that without determination of personal equations by direct comparison of measurements on the same individual crania, it is not possible at present to compare simotic indices found by different craniologists.

TABLE II.

Values of the Simotic Index.

Race	Mérejkowsky		Race	Ryley	
	♂	♀		♂	♀
Negroes	25·6	—	Congo	25·6	25·7
Malays	31·3	—	Moluccas	26·5	—
New Caledonians ...	38·5	30·6	Gaboon, 1880 ...	29·0	22·9
Mongols	40·5	—	Sumatra	29·2	—
Melanesians	41·9	35·2	Celebes	29·7	—
Marquesas Island ...	43·9	34·0	Borneo	30·2	34·7
Maoris	47·9	43·3	Philippines	30·4	29·0
American Indians ...	48·0	46·2	Gaboon, 1864 ...	30·9	27·7
New Hebrides ...	49·1	44·5	Malay	33·7	—
Hindoos	51·1	42·5	Java and Madura ...	33·9	32·7
Auvergnats	51·8	45·0	Nubians	34·1	23·4
Gypsies	53·8	—	Ainos	43·4	—
Tahitians	54·3	—	Veddahs	43·6	36·9
French	54·8	47·1	Egyptians	44·4	36·9
Dutch	58·6	55·2	Hindoos	44·7	39·1
French Cymry ...	59·6	50·3	English	50·8	46·6

In two points, however, we agree fairly well with Mérejkowsky, i.e. in the general order of races and in the fact that the simotic index is a marked sexual character. In all cases—22 in number—except the Congo and Borneo crania, the female has a lower simotic index than the male and this is true for the apes, where we can determine it:

	♂	♀
Chimpanzee	21·4	18·5
Gorilla	56·8	55·1

The two exceptions are the Congo crania, where the two sexes are practically alike, and the crania from Borneo, where the female has the higher simotic index, but the probable errors being introduced, i.e. Borneo: ♂'s $30·2 \pm 1·2$, ♀'s $34·7 \pm 2·1$, show us that even here the difference is quite possibly non-significant. Thus we conclude that in the female the nasal bones are flatter than in the male, and this secondary sexual character may be used—as far as it is ocularly appreciable—as a help in sexing. It may be remarked—in order to avoid circular reasoning—that

with the possible exception of Dr Derry's classifications, the judgment in sexing has not been influenced by nasal characters*.

While it appears to us that the difference of sexing will not be greater than that of two small samples of the same race and less probably than the difference of measurement of two different craniologists, we have still to answer the important question of how far the same craniologist will repeat results in the case of these delicate nasal measurements. We are able to make some interesting comparisons from this standpoint. K. V. Ryley made her first measurements of the nose on the Whitechapel, Egyptian, Congo and Gaboon series in the summer of 1911 for use in the paper on the negro skull (*Biometrika*, Vol. VIII. p. 316). She was then new to these particular measurements, and before the second series were made she had nearly a year's practice on a great variety of races. In the English Whitechapel series 13 crania measured in one series (1911) are not in the other series (1912), that is to say one quarter of the crania are not the same in the two series. These 13 crania of the first series were originally Museum specimens, i.e. skulls having some abnormality (other than nasal), or remarkable feature, and placed in the Anatomical Museum for exhibition. It was thought better to exclude these individuals in the second series and replace them by more normal examples. Thus the divergencies between the *A* (1911) and *B* (1912) English series are not solely due to personal equation. The Congo and Gaboon 1864 series are practically the same crania for *A* and *B* as nearly every skull which was measurable was measured on each occasion.

The two Egyptian series are not the same crania, for they consisted of the 100 crania of the series of 1800 skulls, which were being otherwise measured at the time when these nasal measurements were taken. Thus we may conclude that the Congo and Gaboon 1864 series represent changes due to the same measurer repeating operations at the beginning and end of a period during which experience was growing and methods being standardised; the Egyptian series represent this variation in the measurer together with the difference between random samples; and the English series represent not only the variation due to the measurer, but further the effect of modifying by 25 °/₀ the actual sample

* Dr Derry does give weight to nasal features in sexing, but if we examine the results in Table I from this standpoint, we have

Difference of male and female, i.e. ♂ − ♀.

	m_α	$m_{\alpha'}$	m_β	m_S
Professor Thane	7·1	6·1	9·6	11·1
Dr Derry ...	9·2	8·9	13·9	10·2

It will be clear from these results that Dr Derry used the mesodacryal indices, i.e. the entire bridge of the nose, rather than the nasal bones in his sexual appreciation; for he has a less sexual difference in the simotic index than Professor Thane, while he has greater values in the mesodacryal indices. As a matter of fact the sexual differences in the Nubians seem to us of such an exaggerated character, that we venture to suggest that the females may have been captives and thus may be more definitely negresses, with whom their indices accord, than the males were negroes; the males being possibly a conquering race.

measured. Finally to test the extent to which K. V. Ryley's methods were finally standardised, a third measurement of the male Whitechapel crania was made four months later than *B*, namely *C* in December, 1912. In the case of *C* the same 50 crania exactly were remeasured*. There now resulted a very close accordance between all the measurements absolute and indicial. It will be noticed on examination of the Table that:

(i) The error in the value of the simotic index due to variation of personal equation never exceeds a point.

TABLE III.

Comparison of Measurements on the Nasal Bridge made at intervals and on different samples.

Series	Meso-dacryal Chord (*DC*)	Meso-dacryal arc (*DA*)	Simotic Chord (*SC*)	Simotic Subtense (*SS*)	Meso-dacryal Index β	Meso-dacryal Index α' (from β)	Simotic Index (*S*)	Remarks
Gaboon, 1864, *A* ♂	24·5 ± ·2	33·5 ± ·3	9·16 ± ·26	2·87 ± ·11	42·7 ± ·9	45·4 ± ·6	30·8 ± ·9	Same
„ „ *B* ♂	23·2 ± ·2	32·4 ± ·3	9·43 ± ·26	2·88 ± ·11	40·0 ± ·8	43·6 ± ·5	30·9 ± ·9	crania
„ „ *A* ♀	23·1 ± ·3	32·3 ± ·4	9·55 ± ·28	2·68 ± ·10	44·8 ± 1·3	46·7 ± ·8	28·7 ± 1·0	Same
„ „ *B* ♀	22·5 ± ·3	31·8 ± ·4	9·88 ± ·29	2·68 ± ·11	42·0 ± 1·3	44·9 ± ·8	27·7 ± 1·0	crania
Congo, *A* ♂ ...	24·4 ± ·3	32·8 ± ·4	9·44 ± ·21	2·38 ± ·08	34·5 ± ·9	39·6 ± ·6	25·6 ± ·8	Same
„ *B* ♂ ...	23·9 ± ·3	32·4 ± ·4	9·80 ± ·21	2·48 ± ·09	35·5 ± ·8	40·5 ± ·6	25·6 ± ·7	crania
„ *A* ♀ ...	23·5 ± ·3	32·2 ± ·4	9·46 ± ·33	2·31 ± ·11	36·8 ± 1·0	41·5 ± ·7	25·2 ± 1·3	Same
„ *B* ♀ ...	23·3 ± ·3	30·8 ± ·3	9·72 ± ·35	2·41 ± ·12	32·6 ± ·8	38·6 ± ·6	25·7 ± 1·4	crania
Egyptians, *A* ♂ ...	21·5 ± ·2	34·5 ± ·4	10·58 ± ·18	4·67 ± ·10	61·3 ± 1·5	57·0 ± ·9	44·8 ± ·8	Different
„ *B* ♂ ...	21·5 ± ·2	35·3 ± ·2	10·42 ± ·17	4·63 ± ·10	65·0 ± 1·3	59·4 ± ·8	44·4 ± ·7	samples
„ *A* ♀ ...	20·4 ± ·2	32·4 ± ·2	10·76 ± ·17	4·11 ± ·09	59·3 ± ·9	55·9 ± ·6	38·6 ± ·7	Different
„ *B* ♀ ...	20·6 ± ·3	32·0 ± ·3	10·84 ± ·16	3·97 ± ·09	56·0 ± 1·1	53·9 ± ·7	36·9 ± ·8	samples
English, *A* ♂ ...	22·6 ± ·2	35·1 ± ·3	9·52 ± ·17	4·74 ± ·11	56·2 ± 1·3	53·9 ± ·8	50·7 ± 1·2	25% different
„ *B* ♂ ...	21·5 ± ·2	34·8 ± ·3	9·38 ± ·17	4·68 ± ·10	62·7 ± 1·2	58·0 ± ·7	50·8 ± 1·2	crania
„ *A* ♀ ...	20·9 ± ·2	31·9 ± ·3	8·98 ± ·18	4·14 ± ·07	53·4 ± 1·2	52·2 ± ·8	47·4 ± ·9	25% different
„ *B* ♀ ...	20·6 ± ·2	31·5 ± ·3	9·10 ± ·17	4·16 ± ·07	53·7 ± 1·0	52·5 ± ·6	46·6 ± ·8	crania

TABLE III *bis.*

English Crania, 50 Males.

Series	Meso-dacryal Chord (*DC*)	Meso-dacryal arc (*DA*)	Meso-dacryal Subtense (*DS*)	Simotic Chord (*SC*)	Simotic Subtense (*SS*)	Meso-dacryal Index β	Meso-dacryal Index α'	Meso-dacryal Index α	Simotic Index *S*
B ...	21·5 ± ·2	34·8 ± ·3	12·1 ± ·1	9·38 ± ·17	4·68 ± ·10	62·7 ± 1·2	58·0 ± ·7	56·8 ± ·7	50·8 ± 1·2
C ...	21·4 ± ·2	34·6 ± ·3	12·1 ± ·1	9·43 ± ·17	4·72 ± ·10	62·7 ± 1·2	58·1 ± ·7	57·4 ± ·7	51·2 ± 1·2

A are measurements taken at start of investigation, *B* at conclusion of investigation after practise and standardisation, *B* only used in this memoir. In the Table III *bis* both series, *B* and *C*, were taken on the same crania at the end of the investigation with an interval of four months.

* K. V. Ryley, it is needless to say, had not her earlier values before her when making her remeasurements.

That is, it is of the order of the probable error. It may amount to 1·7, which is only about twice the probable error when we combine the effect of random sampling with personal error.

(ii) The differences in the mesodacryal index β can amount for personal variation to 4·2 (Congo ♀'s), which is as large a value as we obtain on the Egyptian series for combined personal error and random sampling, and even to 6·6 points in the Whitechapel with change of sample and personal variation, which is five times the probable error. Corresponding differences will of course exist in α' deduced from β. We believe that this difference in the early and late values of β is due to greater standardisation of method in determining the dacryon with a rather blunt pointed instrument and to greater mastery of the difficulties arising from damaged crania and in the case of the apes from partially obliterated sutures.

(iii) In the absolute measurements mesodacyral chord (*DC*), mesodacryal subtense (*DS*), mesodacyral arc (*DA*), simotic chord (*SC*), simotic subtense (*SS*) there is a maximum error in the means of about 4·5 %, but this is rare, and reduces to insignificance with practise in the measurements*.

(iv) A comparison of *B* and *C* shows that in all cases after continuous practise and standardisation of method, the variations in absolute measurements or in indices are less than the probable errors of random sampling.

Of course the whole of the above remarks apply to a comparison of *mean* values and not to measurements on an individual cranium. We should conclude as follows:

(*a*) The measurements on the nasal bridge need great care, and the same measurer may on repetition differ considerably from a previous determination on the same skull.

(*b*) But with long practise and careful standardisation of method the racial values obtained will repeat themselves, if the series be measured afresh, and values obtained by the same recorder are quite intercomparable.

(*c*) We are doubtful—especially having regard to Mérejkowsky's results—whether racial values obtained by different craniologists, who are fresh to this side of cranial measurement, or who have not tested their personal equation on the same series, will be directly comparable.

(*d*) Notwithstanding these difficulties, which are really only an intensification of difficulties which occur in all branches of craniometry, we believe these measurements on the nasal bridge to be really valuable and think that they ought to occupy more attention. They are of course only a phase of what may reach greater importance in the future: namely of what we may term *micrometric* as distinguished from the usual or *macrometric* measurements of the skull.

* The earlier series of measurements tended rather to exaggerate the mesodacryal chord and arc.

There are bones other than those of the nasal bridge which might give racially significant micrometric measurements, although specially designed apparatus, or an adaption of existing physical instruments as yet unused in craniometry, would have to be employed in their determination.

(3) *On the observed* (α) *and calculated* (α') *values of the subtense mesodacryal index.*

In the discussion on the negro skull (*loc. cit.* pp. 297, 316) it was pointed out that our original measurements of the mesodacryal chord and arc leading to the index β did not enable us to determine the subtense directly, or indirectly, until some assumption was made as to the shape of the bridge of the nose. We were not at the time these measurements were suggested to Dr Crewdson-Benington aware of Mérejkowsky's instrument, which is as available for finding the mesodacryal subtense as for its designed purpose the determination of the simotic subtense. Accordingly after some consideration the catenary was selected as a fairly suitable curve for the nasal bridge and by means of it the value of the subtense mesodacryal index (α') was deduced from β. In the present investigation α has been found directly and it is of much interest to test the legitimacy of the catenary hypothesis.

TABLE IV. *Differences* $\alpha' - \alpha$ *of Calculated* (α') *and Observed* (α) *Values of Mesodacryal Subtense Index.*

	♂	♀	Average
Gorilla	0·21	0·07	0·14
Ainos	0·36	—	0·36
Negroes (Gaboon (1864 + 1880)	1·01	0·88	0·94
Negroes (Congo	1·45	1·37	1·41
English	1·19	−0·47	0·36
Egyptians	1·53	1·12	1·32
Chimpanzees	1·64	1·41	1·52
Philippine Islands	1·10	2·16	1·63
Moluccas	1·63	—	1·63
Hindoos	1·79	3·12	2·45
Celebes	2·41	—	2·41
Borneo	2·76	3·86	3·31
Javanese	2·20	2·80	2·50
Sumatra	3·73	—	3·73
Veddahs	4·58	4·99	4·78
Orang-utans	17·33	20·23	18·78
Gibbons	♂ + ♀ + ♂ (*Hylobates* 18·60 / *Symphalangus* 14·22)		18·60 / 14·22

We see, to judge by this Table, that the hypothesis of the catenary suits the Gorilla and the Aino nose very closely; it is fairly good for Negro, English and

Egyptian, roughly we must subtract one point from the calculated to get the actual value of the index; for the Chimpanzee, the Hindoos and the inhabitants of the Philippine and Molucca Islands two points must be subtracted; for those of the Celebes, Borneo, Java and Sumatra three points, for the Veddahs five points, and for the Orang-utan and Gibbon 14 to 20! Thus as we pass from Africa and the region of the Gorilla through Europe to Asia and to the East Indian Islands and the region of the Orang-utan we get roughly a continuous divergence from the catenary hypothesis, which fits the Gorilla, to a markedly non-catenary relation as in the case of the Orang*. While the Aino and Veddah have equal flatness of the nasal bones as measured by the simotic index, they stand at opposite ends of the scale with regard to a catenary hypothesis of the whole bridge of the nose. No attempt, however, is made to deduce any racial order from Table IV although it is not without suggestiveness.

Another method of approaching the degree of relationship of α' to α is to consider the correlation coefficient between them, $r_{\alpha\alpha'}$. A glance at Table XX shows that it is very high. We have, averaging results:

TABLE V. *Correlation* $r_{\alpha\alpha'}$.

Chimpanzees and Orang-utans	·754
Gibbons (*Hylobates*)	·815
East Asiatic Group	·878
Gorillas	·906
Negro Group	·923
Hindoos	·931
Egyptians and English	·964
Veddahs	·965

Finally in order to calculate the value of α from α' for a given individual of one of the races dealt with, we append the regression lines, which provide the most probable value of α for a given α'.

TABLE VI.

Male		Female	
Orang-utans	$\alpha = \cdot6697\alpha' + 12\cdot99$	*Orang-utans*	$\alpha = \cdot5053\alpha' + 28\cdot98$
Chimpanzees	$\alpha = \cdot6629\alpha' + \text{ε}\ 66$	*Chimpanzees*	$\alpha = \cdot6096\alpha' + 10\cdot50$
Veddahs	$\alpha = \cdot8324\alpha' + 5\cdot75$	*Gorillas*	$\alpha = \cdot8404\alpha' + 7\cdot11$
Congo	$\alpha = \cdot8431\alpha' + 4\cdot91$	Egyptians	$\alpha = \cdot8877\alpha' + 4\cdot93$
Egyptians	$\alpha = \cdot9359\alpha' + 2\cdot25$	Gaboon, 1880	$\alpha = \cdot8842\alpha' + 4\cdot28$
Philippine	$\alpha = \cdot9448\alpha' + 1\cdot25$	Gaboon, 1864	$\alpha = \cdot8931\alpha' + 3\cdot94$
Javanese	$\alpha = \cdot9359\alpha' + \cdot82$	English	$\alpha = 1\cdot0037\alpha' + \cdot27$
Gaboon, 1864	$\alpha = \cdot9782\alpha' + \cdot23$	Congo	$\alpha = \cdot9739\alpha' - \cdot36$
English	$\alpha = \cdot9756\alpha' + \cdot22$	"Mixed" Malays	$\alpha = 1\cdot0420\alpha' - 5\cdot76$
Hindoos	$\alpha = \cdot9665\alpha' + \cdot11$	Veddahs	$\alpha = 1\cdot1203\alpha' - 12\cdot71$
Borneo	$\alpha = \cdot9645\alpha' - 1\cdot16$	[*Gibbons, Hylobates* ♂ + ♀ + ♂	$\alpha = \cdot7083\alpha' - 2\cdot41$]
Gaboon, 1880	$\alpha = 1\cdot0045\alpha' - 2\cdot09$		
Gorillas	$\alpha = 1\cdot0750\alpha' - 3\cdot29$		

* The reader will observe (see contours, pp. 428—9) that it is not proper to speak of a catenary *form* of the nose. The English and Gorilla noses are not at all catenary in contour, but the chord and subtense relation is on the average clearly that of the catenary chord and subtense.

It will be seen that the catenary assumption as to the bridge of the nose, notwithstanding the relatively high correlations of α and α', is not very satisfactory*. If it were, the best fitting or regression line would be simply $\alpha = \alpha'$. Thus the regression coefficient should be unity and the constant term zero. This is roughly true for English females, less true for English and Hindoo males, and approximately the case in Congo females and Gaboon (1864) males. For the anthropoids the deviations are very considerable, and this is also true for the Veddahs. The catenary form of the nose appears to be an impression largely based on familiarity with the higher racial types. Thus the mesodacryal subtense index α can only be deduced from the mesodacryal arcual index β for *individuals* of the higher races. At the same time Table IV shows that the *racial* value α' of α as deduced from β is very little in excess of the true value for a number of races, and we conclude that the hypothesis has greater value for interracial than for intraracial comparisons†.

(4) *On the Simotic and Mesodacryal Indices.*

If we are going to use these indices as a racial scale, it becomes of some importance to determine which provides the better classification. Unfortunately the simotic index cannot be determined for the Orang-utan. But an examination of Table IX shows that the Chimpanzee is placed at one end, the Gorilla at

* It serves excellently, however, as a control of individual measurements, and when α' is not approximately α it is always worth reconsidering the measurements involved.

† In order to obtain the values of α' from those of β for the catenary hypothesis in the case of the Chimpanzee and Orang-utan, the table published in *Biometrika*, Vol. VIII. pp. 338—9, had to be somewhat extended. The values in Table VII below were obtained.

TABLE VII.

Supplementary Tables for Subtense Mesodacryal Index α as calculated from the arcual value β on the Catenary Hypothesis.

(A) Values of α.

β	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
6	15·3	15·4	15·6	15·7	15·8	16·0	16·1	16·2	16·3	16·5
7	16·6	16·7	16·8	17·0	17·1	17·2	17·3	17·4	17·6	17·7
8	17·8	17·9	18·0	18·1	18·3	18·4	18·5	18·6	18·7	18·8
9	18·9	19·1	19·2	19·3	19·4	19·5	19·6	19·7	19·8	19·9
10	20·0	20·1	20·2	20·3	20·4	20·6	20·7	20·8	20·9	21·0
11	21·1	21·2	21·3	21·4	21·5	21·6	21·7	21·8	21·9	22·0
12	22·1	22·2	22·3	22·4	22·5	22·6	22·7	22·8	22·9	23·0

the other end of the simotic scale*, while in the case of the mesodacryal indices the Chimpanzee and Gorilla although widely separated from each other are both placed at the low end of the scale next the Negroes, while the Orang-utan appears next the Veddahs at the top of the scale. This appears an arrangement at least more in keeping with geographical relations, although we make no assertion that similarity in nasal form between Veddah and Orang and again between Negro and Gorilla or Chimpanzee is due either to closer descent relationship, or to a common environment compelling species dwelling under it to follow similar nasal developments†. As far as the mesodacryal indices are concerned, English, Egyptian and Hindoo are closer to the Veddah than they are to the Negro, and may in nasal form be considered closer to the Orang than to

TABLE VII. (*continued*).

(B)

β	a	β	a	β	a	β	a	β	a	β	a
101	80·2	*126*	94·0	*151*	107·5	*176*	120·8	*201*	133·9	*226*	147·0
102	80·8	*127*	94·5	*152*	108·0	*177*	121·3	*202*	134·5	*227*	147·5
103	81·3	*128*	95·1	*153*	108·5	*178*	121·8	*203*	135·0	*228*	148·0
104	81·9	*129*	95·6	*154*	109·1	*179*	122·4	*204*	135·5	*229*	148·6
105	82·4	*130*	96·2	*155*	109·6	*180*	122·9	*205*	136·0	*230*	149·1
106	83·0	*131*	96·7	*156*	110·2	*181*	123·4	*206*	136·6	*231*	149·6
107	83·5	*132*	97·2	*157*	110·7	*182*	124·0	*207*	137·1	*232*	150·1
108	84·1	*133*	97·8	*158*	111·2	*183*	124·5	*208*	137·6	*233*	150·6
109	84·6	*134*	98·3	*159*	111·8	*184*	125·0	*209*	138·1	*234*	151·2
110	85·2	*135*	98·9	*160*	112·3	*185*	125·5	*210*	138·7	*235*	151·7
111	85·8	*136*	99·4	*161*	112·8	*186*	126·1	*211*	139·2	*236*	152·2
112	86·3	*137*	99·9	*162*	113·4	*187*	126·6	*212*	139·7	*237*	152·7
113	86·9	*138*	100·5	*163*	113·9	*188*	127·1	*213*	140·2	*238*	153·2
114	87·4	*139*	101·0	*164*	114·4	*189*	127·7	*214*	140·8	*239*	153·8
115	88·0	*140*	101·6	*165*	114·9	*190*	128·2	*215*	141·3	*240*	154·3
116	88·5	*141*	102·1	*166*	115·5	*191*	128·7	*216*	141·8	*241*	154·8
117	89·1	*142*	102·7	*167*	116·0	*192*	129·2	*217*	142·3	*242*	155·3
118	89·6	*143*	103·2	*168*	116·5	*193*	129·8	*218*	142·8	*243*	155·8
119	90·1	*144*	103·7	*169*	117·1	*194*	130·3	*219*	143·4	*244*	156·3
120	90·7	*145*	104·3	*170*	117·6	*195*	130·8	*220*	143·9	*245*	156·9
121	91·2	*146*	104·8	*171*	118·1	*196*	131·3	*221*	144·4	*246*	157·4
122	91·8	*147*	105·3	*172*	118·7	*197*	131·8	*222*	144·9	*247*	157·9
123	92·3	*148*	105·9	*173*	119·2	*198*	132·4	*223*	145·4	*248*	158·4
124	92·9	*149*	106·4	*174*	119·7	*199*	132·9	*224*	146·0	*249*	159·0
125	93·4	*150*	106·9	*175*	120·2	*200*	133·4	*225*	146·5	*250*	159·5

* There is slender evidence also to place the Orang-utan out of position below the Chimpanzee and Negroes in the matter of this index.

† Dr Hans Friedenthal (*Beiträge zur Naturgeschichte des Menschen*, Th. v. "Sonderform der menschlichen Leibsbildung," Jena, 1910, S. 61) considers the nasal form determined by environmental conditions: "Die anthropoiden Affen als Baumbewohner bedurften keiner Vervolkommung der Atemröhre während der Reduktion des Riechorgans, wie die bodenbewohnenden Menschen und Paviane. Die Gorilla, mehr dem Bodenleben angepasst als die übrigen Anthropoiden, ja, mehr als viele Ostaffen und Westaffen, zeigt eine ausgebildetere äussere Nase als Schimpanse, Orang und Hylobates."

TABLE VIII. *Man and the Anthropoid Apes. Means of Nasal Bridge Measurements.*

		Mesodacryal Chord	Mesodacryal Arc	Mesodacryal Subtense	Simotic Chord	Simotic Subtense	Index α	Index α'	Index β	Index S
Males	Congo	*50* 23·93 ± ·26	*50* 32·39 ± ·38	*50* 9·32 ± ·15	*50* 9·80 ± ·21	*50* 2·48 ± ·09	*50* 39·09 ± ·54	*50* 40·54 ± ·57	*50* 35·48 ± ·83	*50* 25·58 ± 1·73
	Gaboon, 1864	*48* 23·16 ± ·18	*48* 32·38 ± ·28	*48* 9·91 ± ·13	*47* 9·43 ± ·26	*47* 2·88 ± ·11	*48* 42·91 ± ·55	*48* 43·63 ± ·51	*48* 39·96 ± ·75	*47* 30·90 ± ·87
	Gaboon, 1880	*16* 23·16 ± ·46	*16* 32·64 ± ·40	*16* 9·78 ± ·19	*16* 8·30 ± ·40	*16* 2·30 ± ·11	*16* 42·93 ± 1·29	*16* 44·82 ± 1·25	*16* 41·93 ± 1·91	*16* 29·01 ± 1·49
	Philippine Islands ...	*17* 20·31 ± ·29	*17* 28·12 ± ·35	*17* 8·42 ± ·24	*17* 8·42 ± ·31	*17* 2·55 ± ·13	*17* 41·55 ± 1·08	*17* 42·65 ± ·83	*17* 38·48 ± 1·26	*17* 30·40 ± 1·09
	Moluccas	*8* 21·41	*8* 30·19	*8* 9·15	*8* 9·36	*8* 2·48	*8* 42·86	*8* 44·49	*8* 41·15	*8* 26·53
	Borneo	*26* 21·25 ± ·32	*26* 30·06 ± ·32	*26* 8·86 ± ·14	*26* 7·93 ± ·24	*26* 2·33 ± ·10	*26* 42·24 ± 1·06	*26* 45·00 ± 1·04	*26* 42·19 ± 1·65	*26* 30·15 ± 1·24
	Malays	*14* 21·12 ± ·48	*14* 29·96 ± ·64	*14* 9·23 ± ·22	*14* 7·76 ± ·35	*14* 2·62 ± ·17	*14* 44·16 ± 1·14	*14* 45·25 ± 1·24	*14* 42·50 ± 1·90	*14* 33·71 ± 1·41
	Celebes	*9* 21·31	*9* 30·78	*9* 9·40	*9* 8·54	*9* 2·58	*9* 44·52	*9* 46·93	*9* 45·12	*9* 29·74
	Sumatra	*9* 22·03	*9* 32·56	*9* 9·86	*8* 10·10	*8* 2·88	*9* 44·73	*9* 48·46	*9* 47·44	*8* 29·18
	Java and Madura ...	*39* 21·63 ± ·23	*39* 31·36 ± ·33	*39* 9·63 ± ·18	*39* 8·83 ± ·22	*39* 2·99 ± ·12	*39* 44·95 ± ·94	*39* 47·15 ± ·95	*39* 45·60 ± 1·48	*39* 33·88 ± 1·21
	Nubians*	*17* 24·21	*17* 36·49	*17* 11·72	*17* 11·45	*17* 3·74	*17* 48·47	*17* 50·37	*17* 50·60	*17* 34·07
	Ainos	*6* 20·88	*6* 31·42	*6* 10·42	*6* 8·80	*6* 3·80	*6* 49·92	*6* 50·28	*6* 50·45	*6* 43·37
	Hindoos	*10* 19·47 ± ·44	*10* 31·20 ± ·68	*10* 10·66 ± ·33	*10* 8·71 ± ·35	*10* 3·78 ± ·18	*10* 54·95 ± 1·54	*10* 56·74 ± 1·49	*10* 60·68 ± 2·44	*10* 44·70 ± 2·25
	English	*50* 21·47 ± ·21	*50* 34·78 ± ·26	*50* 12·09 ± ·11	*50* 9·38 ± ·17	*50* 4·68 ± ·10	*50* 56·78 ± ·71	*50* 57·97 ± ·70	*50* 62·72 ± 1·16	*50* 50·83 ± 1·17
	Egyptians	*50* 21·52 ± ·20	*50* 35·34 ± ·23	*50* 12·34 ± ·12	*50* 10·42 ± ·17	*50* 4·63 ± ·10	*50* 57·82 ± ·72	*50* 59·35 ± ·75	*50* 65·05 ± 1·25	*50* 44·38 ± ·69
	Veddahs	*15* 20·14 ± ·44	*15* 33·87 ± ·69	*15* 11·43 ± ·28	*16* 9·14 ± ·28	*16* 3·93 ± ·15	*15* 57·08 ± 1·25	*15* 61·66 ± 1·44	*15* 68·92 ± 2·41	*16* 43·58 ± 1·65
	Chimpanzees	*33* 18·86 ± ·33	*33* 22·99 ± ·42	*33* 5·44 ± ·15	*13* 8·32 ± ·34	*13* 1·78 ± ·14	*33* 28·91 ± ·66	*33* 30·55 ± ·67	*33* 22·02 ± ·84	*13* 21·42 ± 1·43
	Gorillas	*27* 22·76 ± ·52	*27* 30·78 ± ·55	*27* 9·04 ± ·21	*21* 6·47 ± ·30	*21* 3·31 ± ·11	*27* 40·82 ± 1·26	*27* 41·03 ± 1·04	*27* 36·43 ± 1·50	*21* 56·80 ± 3·26
	Orang-utans	*44* 15·43 ± ·24	*44* 33·76 ± ·57	*44* 11·16 ± ·20	—	—	*44* 74·45 ± 1·89	*44* 91·78 ± 2·39	*44* 122·78 ± 4·38	—
Both Sexes	*Gibbons* {*Hylobates*	*25* 10·54 ± ·15	*25* 16·70 ± ·29	*25* 3·85 ± ·13	*16* 5·33 ± ·13	*16* 0·46 ± ·04	*25* 36·88 ± 1·18	*25* 55·48 ± 1·36	*25* 58·87 ± 2·22	*16* 8·66 ± ·75
	Gibbons {*Symphalangus*	*9* 13·17	*9* 18·53	*9* 3·89	*6* 6·00	*6* 0·62	*9* 28·98	*9* 43·20	*9* 39·77	*6* 10·15
Females	Congo	*27* 23·27 ± ·26	*27* 30·81 ± ·32	*27* 8·63 ± ·16	*25* 9·72 ± ·35	*25* 2·41 ± ·12	*27* 37·22 ± ·67	*27* 38·59 ± ·60	*27* 32·60 ± ·82	*25* 25·70 ± 1·37
	Gaboon, 1864	*37* 22·52 ± ·32	*37* 31·81 ± ·37	*37* 9·82 ± ·17	*35* 9·88 ± ·29	*35* 2·68 ± ·11	*37* 44·01 ± ·80	*37* 44·87 ± ·84	*37* 42·04 ± 1·27	*35* 27·71 ± ·97
	Gaboon, 1880	*18* 21·84 ± ·33	*18* 31·00 ± ·50	*18* 9·60 ± ·24	*18* 9·46 ± ·27	*18* 2·13 ± ·13	*18* 44·14 ± 1·11	*18* 45·09 ± 1·21	*18* 42·34 ± 1·88	*18* 22·86 ± 1·49
	Philippine Islands ...	*5* 19·36	*5* 28·00	*5* 8·66	*4* 8·80	*4* 2·58	*5* 44·84	*5* 47·00	*5* 45·04	*4* 29·00
	Borneo	*12* 19·68 ± ·33	*12* 27·88 ± ·43	*12* 8·00 ± ·20	*11* 7·66 ± ·40	*11* 2·59 ± ·19	*12* 41·07 ± 1·35	*12* 44·93 ± 1·06	*12* 41·92 ± 1·61	*11* 34·71 ± 2·06
	Javanese	*6* 19·42	*6* 27·58	*6* 8·18	*6* 8·58	*6* 2·80	*6* 42·75	*6* 45·55	*6* 43·10	*6* 32·67
	Nubians*	*19* 23·37	*19* 32·08	*19* 9·22	*19* 11·90	*19* 2·81	*19* 40·32	*19* 42·82	*19* 38·87	*19* 23·48
	Hindoos	*5* 18·90	*5* 29·00	*5* 9·24	*5* 7·86	*5* 3·02	*5* 49·38	*5* 52·50	*5* 53·74	*5* 39·06
	English	*50* 20·55 ± ·19	*50* 31·50 ± ·28	*50* 10·81 ± ·12	*50* 9·10 ± ·17	*50* 4·16 ± ·07	*50* 52·92 ± ·63	*50* 52·45 ± ·61	*50* 53·70 ± ·98	*50* 46·58 ± ·77
	Egyptians	*50* 20·63 ± ·25	*50* 32·04 ± ·33	*50* 10·78 ± ·12	*50* 10·84 ± ·16	*50* 3·97 ± ·09	*50* 52·74 ± ·63	*50* 53·86 ± ·69	*50* 56·02 ± 1·12	*50* 36·94 ± ·79
	Veddahs	*12* 18·52 ± ·44	*12* 31·83 ± ·59	*12* 10·70 ± ·29	*12* 8·28 ± ·33	*12* 3·08 ± ·20	*12* 59·24 ± 2·44	*12* 64·23 ± 2·11	*12* 73·38 ± 3·65	*12* 36·86 ± 2·62
	Chimpanzees	*18* 17·63 ± ·54	*18* 21·45 ± ·63	*18* 5·09 ± ·20	*9* 8·07 ± ·18	*9* 1·47 ± ·13	*18* 29·09 ± ·96	*18* 30·50 ± 1·24	*18* 22·29 ± 1·54	*9* 18·53 ± 1·73
	Gorillas	*25* 20·22 ± ·51	*25* 28·58 ± ·62	*25* 8·88 ± ·21	*19* 5·31 ± ·23	*19* 2·82 ± ·16	*25* 44·87 ± 1·16	*25* 44·94 ± 1·28	*25* 42·74 ± 1·93	*19* 55·07 ± 3·15
	Orang-utans	*13* 11·85 ± ·26	*13* 27·75 ± ·65	*13* 9·29 ± ·22	—	—	*13* 79·24 ± 2·48	*13* 99·47 ± 3·51	*13* 136·55 ± 6·50	—

* Mean of results obtained by two sexings.

the Chimpanzee, although all the races dealt with are nearer to the Gorilla than either of the two apes. The following table gives the racial order for the simotic and two mesodacryal indices:

TABLE IX.

Simotic and Mesodacryal Indices. Mean Values.*

Simotic Index (*S*)				Mesodacryal (Subtense) Index (α)				Mesodacryal (Arcual) Index (β)			
♂		♀		♂		♀		♂		♀	
[*Orang-utans*	0?]	[*Orang-utans*	17?]	—		—		—		—	
Chimpanzees	21	*Chimpanzees*	19	*Chimpanzees*	29	*Chimpanzees*	29	*Chimpanzees*	22	*Chimpanzees*	22
Congo	26	Nubians†	23	Congo	39	Congo	37	Congo	35	Congo	33
Moluccas	27	—		*Gorillas*	41	Nubians†	40	*Gorillas*	36	—	
Gaboon, 1880	29	Gaboon, 1880	23	Philippines	42	Borneo	41	Philippines	38	—	
Sumatra	29	Congo	26	Borneo	42	Javanese	43	Gaboon, 1864	40	Nubians†	39
Celebes	30	—		Moluccas	43	Gaboon, 1880	44	Moluccas	41	Gaboon, 1864	42
Borneo	30	—		Gaboon, 1864	43	Gaboon, 1864	44	Gaboon, 1880	42	Gaboon, 1880	42
Philippines	30	Gaboon, 1864	28	Gaboon, 1880	43	*Gorillas*	45	Borneo	42	Borneo	42
Gaboon, 1864	31	Philippines	29	Malays	44	Philippines	45	Malays	43	*Gorillas*	43
Malays	32	—		Celebes	45	—		Celebes	45	Javanese	43
Javanese	34	Javanese	33	Sumatra	45	—		Javanese	46	Philippines	45
Nubians†	34	Borneo	35	Javanese	45	—		Sumatra	47	—	
Ainos	43	—		Nubians†	48	—		Ainos	50	—	
Veddahs	44	Veddahs	37	Ainos	50	—		Nubians†	51	—	
Egyptians	44	Egyptians	37	Hindoos	55	Hindoos	49	Hindoos	61	Hindoos	54
Hindoos	45	Hindoos	39	English	57	English	53	English	63	English	54
English	51	English	47	Veddahs	57	Egyptians	53	Egyptians	65	Egyptians	56
Gorillas	57	*Gorillas*	55	Egyptians	58	Veddahs	59	Veddahs	69	Veddahs	73
—		—		*Orang-utans*	74	*Orang-utans*	79	*Orang-utans*	123	*Orang-utans*	137

Now if we compare the results given in this table we see that with one exception, that of the Borneo crania, the simotic index is greater in the males than in the females; but there is a greater agreement between the sexes—the Hindoos, English and Egyptians excepted—in the mesodacryal indices. For the mesodacryal index, α, there are 7 cases (judging from Table VIII, p. 403) in which the female is greater, as against 7 in which the male is greater; for the mesodacryal index β, there are also 7 cases for the male and 7 for the female with greater value, and

* The following are the values for the Gibbons:

		Simotic Index	Mesodacryal (Subtense) Index	Mesodacryal (Arcual) Index
Gibbons	*Hylobates* ♂ + ♀ + ♂	9	37	55
	Symphalangus ♂ + ♀ + ♂	10	29	43

† The position of the "Nubians" confirms the view that the men were more Egyptian and the women almost negroes.

the individual cases are the same for α and β. On the whole it is the lower races for which the female has the greater value, and the higher races—in the scale of civilisation—for which the male has the greater value. Thus the mesodacryal index appears more of a racial and less of a sexual character than the simotic index. Roughly also the two sexes give nearly the same racial order, especially if we regard the large probable errors (see Table VIII, p. 403) of some of our results. Looked at in broad outline we have the nose of the Gorilla closely associated with that of the Negro, and the Negro lies between the Chimpanzee and the Asiatic races. At the bottom of the scale we have the Orang-utans closest of all to the Veddahs, who lie between the Orang-utans and the higher races, so far as such are provided by these measurements*. On the whole the racial scale of the mesodacryal indices seems far more suggestive than that of the simotic index, where the Gorilla is widely separated from the Negro, and is divided from the Veddahs by English, Hindoos and Egyptians†. We believe that a measure of the mesodacryal index is likely to be of as much value as the determination of the simotic index, possibly of greater value.

(5) *On the Absolute Nasal Measurements.*

We are doubtful as to what if any stress can be laid on the absolute measurements. Mérejkowsky, however, cites the absolute values of the simotic subtenses and it is of interest to compare our results with his. This is done in Table X. It will be seen that for Negroes, Malays and "White races" our results are in fair agreement with Mérejkowsky's; with his Melanesian, Polynesian and American groups, we have nothing to compare. There is relatively little difference in the order between the two sexes, but the actual height of the nasal bones, with the one exception of the Borneo crania, is considerably less for the females. This smaller value of the simotic subtense in the female is not true for the chord, which in Nubians, Egyptians, Gaboon (1864), Gaboon (1880), and Philippine Islanders is greater in the female as will be seen in Table XI. There is very little we think to be learnt concerning racial differences in either Table X or Table XI.

The races are mixed in a rather meaningless way—at least we have failed to find any clue to their order, although in this respect the simotic chord appears worse than the simotic subtense. On the whole we believe little of real value is to be learnt from the absolute size of the nasal bones.

* The Gibbons agree with the Orang for the simotic index, but are nearer to the Chimpanzee than to the Orang for the mesodacryal index α, while for the arcual index β their position, like that of the Gorilla, is within the human range.

† Judged by the mesodacryal indices the Gorilla has a flatter nose than any human race, the Negroes approaching most closely; judged by the simotic index the Gorilla has a sharper nose than any human race, the English approaching most closely. At any rate from the standpoint of physiognomy, there can be no doubt that the mesodacryal indices express better the general visual state of affairs: see, however, the contours, pp. 428—9.

TABLE X. *Simotic Subtense* *.

Males		Females		Sex?† Mérejkowsky	
Chimpanzees	1·78	*Chimpanzees*	1·47	—	
Gaboon, 1880	2·30	Gaboon, 1880	2·13	—	
Borneo	2·33	Congo	2·41	—	
Congo	2·45	Philippines	2·58	Negroes	2·60
Moluccas	2·48	—		—	
Philippines	2·55	Borneo	2·59	Mongols	3·00
Celebes	2·58	—		—	
Malays	2·62	—		Malays	2·90
Gaboon, 1864	2·88	Gaboon, 1864	2·68	—	
Sumatra	2·88	—		Polynesians	3·13
Javanese	2·99	Javanese	2·80	—	
Gorillas	3·31	Nubians	2·81	—	
Nubians	3·74	*Gorillas*	2·82	—	
Hindoos	3·78	Hindoos	3·02	—	
Ainos	3·80	—		American Indians	3·80
Veddahs	3·93	Veddahs	3·08	Melanesians	3·85
Egyptians	4·63	Egyptians	3·97	—	
English	4·68	English	4·16	White races	4·74

TABLE XI. *Simotic Chord* ‡.

Males		Females	
Gorillas	6·47	*Gorillas*	5·31
Malays	7·76	—	
Borneo	7·93	Borneo	7·66
Gaboon, 1880	8·30	Hindoos	7·86
Chimpanzees	8·32	*Chimpanzees*	8·07
Philippines	8·42	Veddahs	8·28
Celebes	8·54	—	
Hindoos	8·71	Javanese	8·58
Ainos	8·80	—	
Javanese	8·83	Philippines	8·80
Veddahs	9·14	—	
Moluccas	9·36	English	9·10
English	9·38	—	
Gaboon, 1864	9·43	Gaboon, 1880	9·46
Congo	9·80	Congo	9·72
Sumatra	10·10	Gaboon, 1864	9·88
Egyptians	10·42	Egyptians	10·84
Nubians	11·45	Nubians	11·90

* The Gibbons lie at the very top of this scale close to the Orang-utan with its practically zero value of the subtense. Thus for the simotic subtense we have:

Gibbons, ♂ + ♀ + ♂ { *Hylobates* 0·46 / *Symphalangus* 0·62

† Apparently Mérejkowsky mixes both sexes together, which is hardly permissible considering the large sexual differences.

‡ *Gibbons*, ♂ + ♀ + ♂ { *Hylobates* 5·33 / *Symphalangus* 6·00

(6) *On the Absolute Mesodacryal Measurements.*

The following table gives the order for the mesodacryal subtense, chord and arc:

TABLE XII.

Racial Order of Mesodacryal Measurements.

SUBTENSE				CHORD				ARC			
♂		♀		♂		♀		♂		♀	
Chimpanzees	5·44	*Chimpanzees*	5·09	*Orangs*	15·4	*Orangs*	11·9	*Chimpanzees*	23·0	*Chimpanzees*	21·4
Philippines	8·42	Borneo	8·00	*Chimpanzees*	18·9	*Chimpanzees*	17·6	Philippines	28·1	Javanese	27·6
Borneo	8·86	Javanese	8·18	Hindoos	19·5	Veddahs	18·5	Malays	30·0	—	
Gorillas	9·04	Congo	8·63	Veddahs	20·1	Hindoos	18·9	Borneo	30·1	*Orangs*	27·8
Moluccas	9·15	—		Philippines	20·3	Philippines	19·4	Moluccas	30·2	Borneo	27·9
Malays	9·23	—		Ainos	20·9	—		Celebes	30·8	—	
Congo	9·32	Philippines	8·66	Malays	21·1	—		*Gorillas*	30·8	Philippines	28·0
Celebes	9·40	—		Borneo	21·2	Javanese	19·4	Hindoos	31·2	*Gorillas*	28·6
Javanese	9·63	*Gorillas*	8·88	Celebes	21·3	—		Ainos	31·4	—	
Gaboon (1880)	9·78	Nubians	9·22	Moluccas	21·4	—		Javanese	31·4	Hindoos	29·0
Sumatra	9·86	—		English	21·5	Borneo	19·7	Gaboon (1864)	32·4	Congo	30·8
Gaboon (1864)	9·91	Hindoos	9·24	Egyptians	21·5	*Gorillas*	20·2	Congo	32·4	Gaboon (1880)	31·0
Ainos	10·42	—		Javanese	21·6	English	20·6	Sumatra	32·6	—	
Hindoos	10·66	*Orangs*	9·29	Sumatra	22·0	—		Gaboon (1880)	32·6	—	
Orangs	11·16	Gaboon (1880)	9·60	*Gorillas*	22·8	Egyptians	20·6	*Orangs*	33·8	English	31·5
Veddahs	11·43	Gaboon (1864)	9·82	Gaboon (1864)	23·2	Gaboon (1880)	21·8	Veddahs	33·9	Veddahs	31·8
Nubians	11·72	Veddahs	10·70	Gaboon (1880)	23·2	Gaboon (1864)	22·5	English	34·8	Gaboon (1864)	31·8
English	12·09	Egyptians	10·78	Congo	23·9	Congo	23·3	Egyptians	35·3	Egyptians	32·0
Egyptians	12·34	English	10·81	Nubians	24·2	Nubians	23·4	Nubians	36·5	Nubians	32·1
Gibbons, ♂ + ♀ + ♂		*Hylobates*	3·85	*Gibbons*, ♂ + ♀ + ♂		*Hylobates*	10·54	*Gibbons*, ♂ + ♀ + ♂		*Hylobates*	16·70
		Symphalangus	3·89			*Symphalangus*	13·12			*Symphalangus*	18·53

Now we have already seen that the sexual differences in the mesodacryal indices are not very large, but we notice at once that these sexual differences are very considerable in the absolute measurements. It becomes rather meaningless to assert that the Hindoo's eyes are closer together than the Englishman's, when the difference in mesodacryal chord is less than that between male and female Javanese. They are less for the same reason, namely, because the cranium as a whole is smaller. Practically the female is less—and often very considerably less—in every mesodacryal absolute measurement, and we cannot usefully compare males and females—except as to absolute size, a sexual difference we are already familiar with—unless we get rid of this problem of size by using as we have already done the indices. But surely if this be true for sex, it is also true for race. Our scales become scales of absolute size and of very small racial significance. In all probability absolute lengths or breadths of the head would tell just as much as is to be learnt from these tables of relative racial sizes of the bridge of the nose. In our opinion there is little that has bearing on racial relationships. In, for example, the chord scales, it is possible that Veddah and Orang-utans are close together because of an ancestral link, but the Hindoo appears in this part of the scale because of his small size. The association of the Negroes with the Gorillas may again be partly ancestral, but the association of English and Javanese in the same part of the scale as the Gorillas is probably fortuitous. We are inclined to say that very little indeed can be deduced from absolute scales of this kind for nasal characters.

It is often asserted that a characteristic feature of the negro lies in the fact that he has his eyes farther apart than other races of man. The average value of the mesodacryal chord for the Congo and Gaboon male negroes is 23·5 and for English and Egyptians 21·5 ; for the females, Congo and Gaboon, it is 22·6, and for English and Egyptians 20·6. There is thus 2 mm. difference on the average. Is it possible for the human eye to appreciate this difference? We are inclined to doubt it and believe that it is the marked simotic platygephyrosis (see p. 430 below) of the negro nose which produces largely the impression of greater ocular

Value of Ratio 100 × *Mesodacryal Chord/Minimum Forehead Breadth.*

Race	♂	♀
Congo	24·6	25·1
Gaboon, 1864 ...	24·0	24·3
Gaboon, 1880 ...	23·5	23·5
Egyptians ...	22·6	22·4
Veddahs	22·0	21·2
English	21·9	22·1
Hindoos	21·3	21·0

breadth*. As the total size of the skull varies much from race to race it seems desirable to compare the mesodacryal chord with another horizontal measure and we have taken the minimum forehead breadth: see Table, p. 408.

It will be seen that the Negroes stand at one end of the list and the Indo-Europeans at the other, but again the change of index is relatively small, and it may be legitimately doubted whether it would be visually significant.

(7) *On the relative Racial Variability of the Nasal Bridge Characters.*

Tables XIII and XIV give respectively the Standard Deviations and the Coefficients of Variation of the characters determined in such series as supplied sufficient data for even an attempt at these constants. There is no doubt in our minds that the coefficient of variation is the better measure for racial purposes in the case of absolute measurements. We will consider first what points arise from a discussion of the variability of the mesodacryal subtense, chord and arc from this standpoint. The relative orders of variability are given in Table XV.

Again beyond the broad fact that the apes on the whole are far more variable than the races of men, perhaps little can be learnt from this table. In the apes the female is more variable than the male in 5 out of 9 cases; the same ratio of 5 to 4 is maintained in the case of the negro races; in the lower races from Borneo and the Veddahs, the males are more variable than the females in the ratio of 5 cases to 1, while in the higher races—Egyptian and English—the ratio is 5 cases of the female to 1 case of the male more variable. Altogether therefore the female is more variable in 16 and the male in 14 cases. Generally there is no evidence for greater male variation in these coefficients of variation of the mesodacryal absolute lengths. Even if we based our comparison on the absolute variations of the mesodacryal characters, we find among the apes the male is more variable in 5 the female in 3, with one case—the Chimpanzee mesodacryal subtense—of equality; in the lower races (Veddahs and Borneo) the male is more variable in all 6 cases; in the negro races in 5 out of 9, but in the higher races (English and Egyptian) in only 1 out of 6 cases. Thus in absolute measurement the male is more variable in 17, the female in 12 cases.

* The reader must not judge from Figs. 6—9 of the contours, pp. 428—9. These all have the mesodacryal chord in considerable excess of the negro mean, and were selected to give approximately mean *angles*, not mean absolute lengths.

TABLE XIII. *Man and Anthropoid Apes. Nasal Bridge Characters. Standard Deviations.*

		Mesodacryal Chord	Mesodacryal Arc	Mesodacryal Subtense	Simotic Chord	Simotic Subtense	Index α	Index α'	Index β	Index S
Males	Congo	*50* 2·70 ± ·18	*50* 4·02 ± ·27	*50* 1·53 ± ·10	*50* 2·24 ± ·15	*50* ·91 ± ·06	*50* 5·67 ± ·38	*50* 5·92 ± ·40	*50* 8·67 ± ·58	*50* 7·64 ± ·52
	Gaboon, 1864 ...	*48* 1·89 ± ·13	*48* 2·86 ± ·20	*48* 1·37 ± ·09	*47* 2·66 ± ·18	*47* 1·08 ± ·07	*48* 5·65 ± ·39	*48* 5·22 ± ·36	*48* 7·75 ± ·53	*47* 8·82 ± ·61
	Gaboon, 1880 ...	*16* 2·70 ± ·32	*16* 2·37 ± ·28	*16* 1·11 ± ·13	*16* 2·38 ± ·28	*16* ·67 ± ·08	*16* 7·63 ± ·91	*16* 7·43 ± ·89	*16* 11·32 ± 1·35	*16* 8·81 ± 1·05
	Philippine Islands	*17* 1·76 ± ·20	*17* 2·15 ± ·25	*17* 1·47 ± ·17	*17* 1·91 ± ·22	*17* ·80 ± ·09	*17* 6·60 ± ·76	*17* 5·08 ± ·59	*17* 7·68 ± ·89	*17* 6·64 ± ·77
	Borneo	*26* 2·39 ± ·22	*26* 2·43 ± ·23	*26* 1·08 ± ·10	*26* 1·81 ± ·17	*26* ·77 ± ·07	*26* 8·01 ± ·75	*26* 7·85 ± ·73	*26* 12·49 ± 1·17	*26* 9·35 ± ·88
	Malays	*14* 2·67 ± ·34	*14* 3·53 ± ·45	*14* 1·24 ± ·16	*14* 1·93 ± ·25	*14* ·95 ± ·12	*14* 6·34 ± ·81	*14* 6·90 ± ·88	*14* 10·55 ± 1·34	*14* 7·81 ± 1·00
	Java and Madura	*39* 2·10 ± ·16	*39* 3·05 ± ·23	*39* 1·68 ± ·13	*39* 2·04 ± ·16	*39* 1·15 ± ·09	*39* 8·74 ± ·67	*39* 8·81 ± ·67	*39* 13·72 ± 1·05	*39* 11·20 ± ·86
	Hindoos	*10* 2·04 ± ·31	*10* 3·20 ± ·48	*10* 1·54 ± ·23	*10* 1·62 ± ·24	*10* ·83 ± ·13	*10* 7·23 ± 1·09	*10* 6·97 ± 1·05	*10* 11·46 ± 1·73	*10* 10·55 ± 1·59
	English	*50* 2·16 ± ·15	*50* 2·71 ± ·18	*50* 1·20 ± ·08	*50* 1·77 ± ·12	*50* 1·04 ± ·07	*50* 7·47 ± ·50	*50* 7·32 ± ·49	*50* 12·19 ± ·82	*50* 12·21 ± ·82
	Egyptians ...	*50* 2·05 ± ·14	*50* 2·45 ± ·17	*50* 1·21 ± ·08	*50* 1·75 ± ·12	*50* 1·07 ± ·07	*50* 7·57 ± ·51	*50* 7·89 ± ·53	*50* 13·07 ± ·88	*50* 7·27 ± ·49
	Veddahs ...	*15* 2·51 ± ·31	*15* 3·95 ± ·49	*15* 1·61 ± ·20	*16* 1·68 ± ·20	*16* ·90 ± ·11	*15* 7·16 ± ·88	*15* 8·24 ± 1·01	*15* 13·86 ± 1·71	*16* 9·77 ± 1·16
	Chimpanzees ...	*33* 2·81 ± ·23	*33* 3·61 ± ·30	*33* 1·27 ± ·11	*13* 1·82 ± ·24	*13* ·73 ± ·10	*33* 5·65 ± ·47	*33* 5·74 ± ·48	*33* 7·13 ± ·59	*13* 7·64 ± 1·01
	Gorillas	*27* 3·97 ± ·36	*27* 4·23 ± ·39	*27* 1·66 ± ·15	*21* 2·01 ± ·21	*21* ·73 ± ·08	*27* 9·69 ± ·89	*27* 8·00 ± ·73	*27* 11·56 ± 1·06	*21* 22·15 ± 2·30
	Orang-utans ...	*44* 2·35 ± ·17	*44* 5·56 ± ·40	*44* 1·93 ± ·14	—	—	*44* 18·63 ± 1·34	*44* 23·49 ± 1·69	*44* 43·04 ± 3·09	—
Both Sexes	*Gibbons, Hylobates*	*25* 1·13 ± ·11	*25* 2·12 ± ·20	*25* 0·85 ± ·08	*16* 0·77 ± ·09	*16* 0·26 ± ·03	*25* 8·74 ± ·83	*25* 10·06 ± ·96	*25* 16·43 ± 1·57	*16* 4·48 ± ·53
Females	Congo	*27* 2·00 ± ·18	*27* 2·43 ± ·22	*27* 1·20 ± ·11	*25* 2·58 ± ·25	*25* ·90 ± ·09	*27* 5·15 ± ·47	*27* 4·58 ± ·42	*27* 6·35 ± ·58	*25* 10·15 ± ·97
	Gaboon, 1864 ...	*37* 2·86 ± ·22	*37* 3·35 ± ·26	*37* 1·51 ± ·12	*35* 2·57 ± ·21	*35* ·92 ± ·07	*37* 7·19 ± ·56	*37* 7·61 ± ·60	*37* 11·49 ± ·90	*35* 8·47 ± ·68
	Gaboon, 1880 ...	*18* 2·10 ± ·24	*18* 3·15 ± ·35	*18* 1·52 ± ·17	*18* 1·69 ± ·19	*18* ·83 ± ·09	*18* 7·00 ± ·78	*18* 7·60 ± ·85	*18* 11·84 ± 1·33	*18* 9·38 ± 1·05
	Borneo	*12* 1·69 ± ·23	*12* 2·23 ± ·31	*12* 1·01 ± ·14	*11* 1·94 ± ·28	*11* ·95 ± ·14	*12* 6·94 ± ·96	*12* 5·46 ± ·75	*12* 8·24 ± 1·13	*11* 10·15 ± 1·46
	English	*50* 2·04 ± ·14	*50* 2·90 ± ·20	*50* 1·27 ± ·09	*50* 1·81 ± ·12	*50* ·78 ± ·05	*50* 6·64 ± ·45	*50* 6·36 ± ·43	*50* 10·25 ± ·69	*50* 8·09 ± ·55
	Egyptians ...	*50* 2·59 ± ·17	*50* 3·47 ± ·23	*50* 1·22 ± ·08	*50* 1·66 ± ·11	*50* ·90 ± ·06	*50* 6·62 ± ·45	*50* 7·19 ± ·49	*50* 11·76 ± ·79	*50* 8·24 ± ·56
	Veddahs	*12* 2·27 ± ·31	*12* 3·04 ± ·42	*12* 1·49 ± ·21	*12* 1·72 ± ·24	*12* 1·03 ± ·14	*12* 12·52 ± 1·72	*12* 10·86 ± 1·49	*12* 18·77 ± 2·58	*12* 13·45 ± 1·85
	Chimpanzees ...	*18* 3·38 ± ·38	*18* 3·93 ± ·44	*18* 1·27 ± ·14	*9* ·82 ± ·13	*9* ·58 ± ·09	*18* 6·05 ± ·68	*18* 7·77 ± ·87	*18* 9·70 ± 1·09	*9* 7·69 ± 1·22
	Gorillas	*25* 3·75 ± ·36	*25* 4·57 ± ·44	*25* 1·59 ± ·15	*19* 1·51 ± ·17	*19* 1·04 ± ·11	*25* 8·61 ± ·82	*25* 9·47 ± ·90	*25* 14·27 ± 1·36	*19* 20·33 ± 2·22
	Orang-utans ...	*13* 1·37 ± ·18	*13* 3·49 ± ·46	*13* 1·20 ± ·16	—	—	*13* 13·27 ± 1·76	*13* 18·78 ± 2·48	*13* 34·72 ± 4·59	—

TABLE XIV. *Man and Anthropoid Apes. Nasal Bridge Characters. Coefficients of Variation.*

		Mesodacryal Chord	Mesodacryal Arc	Mesodacryal Subtense	Simotic Chord	Simotic Subtense	Index α	Index α'	Index β	Index S
Males	Congo	*50* 11·28± ·77	*50* 12·41± ·85	*50* 16·44±1·14	*50* 22·89±1·62	*50* 36·85±2·80	*50* 14·49±1·00	*50* 14·61±1·01	*50* 24·43±1·74	*50* 29·87±2·19
	Gaboon, 1864 ...	*48* 8·15± ·56	*48* 8·83± ·61	*48* 13·84± ·97	*47* 28·15±2·11	*47* 37·35±2·94	*48* 13·16± ·92	*48* 11·98± ·84	*48* 19·39±1·38	*47* 28·54±2·14
	Gaboon, 1880 ...	*16* 11·67±1·41	*16* 7·28± ·87	*16* 11·33±1·37	*16* 28·66±3·69	*16* 29·29±3·78	*16* 17·77±2·18	*16* 16·57±2·03	*16* 26·99±3·44	*16* 30·37±3·94
	Philippine Islands	*17* 8·67±1·01	*17* 7·63± ·89	*17* 17·42±2·08	*17* 22·68±2·76	*17* 31·27±3·95	*17* 15·89±1·88	*17* 11·92±1·40	*17* 19·97±2·40	*17* 21·84±2·64
	Borneo	*26* 11·23±1·06	*26* 8·09± ·76	*26* 12·22±1·16	*26* 22·78±2·24	*26* 32·86±3·39	*26* 18·97±1·84	*26* 17·45±1·68	*26* 29·61±3·00	*26* 31·03±3·17
	Malays	*14* 12·64±1·64	*14* 11·77±1·52	*14* 13·45±1·75	*14* 24·81±3·35	*14* 36·32±5·20	*14* 14·36±1·87	*14* 15·24±1·99	*14* 24·82±3·35	*14* 23·16±3·11
	Java and Madura	*39* 9·72± ·75	*39* 9·73± ·75	*39* 17·46±1·37	*39* 23·06±1·85	*39* 38·38±3·34	*39* 19·45±1·54	*39* 18·70±1·48	*39* 30·10±2·50	*39* 33·06±2·79
	Hindoos	*10* 10·49±1·60	*10* 10·27±1·56	*10* 14·48±2·23	*10* 18·60±2·90	*10* 21·94±3·46	*10* 13·16±2·02	*10* 12·29±1·88	*10* 18·88±2·95	*10* 23·60±3·75
	English	*50* 10·04± ·68	*50* 7·80± ·53	*50* 9·93± ·68	*50* 18·85±1·32	*50* 22·13±1·56	*50* 13·16± ·90	*50* 12·63± ·87	*50* 19·43±1·36	*50* 24·03±1·71
	Egyptians ...	*50* 9·51± ·65	*50* 6·93± ·47	*50* 9·80± ·67	*50* 16·84±1·17	*50* 23·10±1·64	*50* 13·09± ·90	*50* 13·29± ·91	*50* 20·09±1·41	*50* 16·38±1·13
	Veddahs	*15* 12·45±1·56	*15* 11·67±1·46	*15* 14·12±1·77	*16* 18·35±2·26	*16* 23·04±2·89	*15* 12·54±1·57	*15* 13·37±1·68	*15* 20·11±2·57	*16* 22·42±2·80
	Chimpanzees ...	*33* 14·91±1·27	*33* 15·72±1·34	*33* 23·34±2·04	*13* 21·88±3·03	*13* 41·07±6·28	*33* 19·53±1·68	*33* 18·80±1·62	*33* 32·39±2·96	*13* 35·69±5·29
	Gorillas	*27* 17·46±1·65	*27* 13·75±1·29	*27* 18·31±1·74	*21* 31·12±3·54	*21* 21·96±2·39	*27* 23·74±2·30	*27* 19·51±1·86	*27* 31·74±3·19	*21* 38·99±4·63
	Orang-utans ...	*44* 15·22±1·12	*44* 16·46±1·22	*44* 17·28±1·28	—	—	*44* 25·02±1·91	*44* 25·60±1·96	*44* 35·06±2·81	—
Both Sexes	*Gibbons, Hylobates*	*25* 10·67±1·03	*25* 12·69±1·23	*25* 22·05±2·20	*16* 14·49±1·76	*16* 57·15±8·76	*25* 23·70±2·38	*25* 18·13±1·79	*25* 27·90±2·86	*16* 51·72±7·64
Females	Congo	*27* 8·61± ·80	*27* 7·89± ·73	*27* 13·86±1·30	*25* 26·58±2·71	*25* 37·33±4·03	*27* 13·84±1·29	*27* 11·88±1·11	*27* 19·48±1·85	*25* 39·47±4·31
	Gaboon, 1864 ...	*37* 12·68±1·01	*37* 10·54± ·84	*37* 15·34±1·23	*35* 25·97±2·23	*35* 34·50±3·09	*37* 16·34±1·32	*37* 16·95±1·37	*37* 27·34±2·30	*35* 30·58±2·69
	Gaboon, 1880 ...	*18* 9·60±1·09	*18* 10·17±1·16	*18* 15·78±1·82	*18* 17·88±2·07	*18* 39·15±5·03	*18* 15·87±1·83	*18* 16·85±1·95	*18* 27·97±3·38	*18* 41·04±5·33
	Borneo	*12* 8·60±1·19	*12* 7·99±1·11	*12* 12·56±1·76	*11* 25·35±3·87	*11* 36·59±5·93	*12* 16·89±2·39	*12* 12·15±1·70	*12* 19·66±2·81	*11* 29·24±4·55
	English	*50* 9·93± ·68	*50* 9·21± ·63	*50* 11·74± ·80	*50* 19·85±1·39	*50* 18·83±1·31	*50* 12·55± ·86	*50* 12·14± ·83	*50* 19·09±1·33	*50* 17·36±1·21
	Egyptians ...	*50* 12·57± ·86	*50* 10·83± ·74	*50* 11·32± ·77	*50* 15·28±1·05	*50* 22·78±1·61	*50* 12·56± ·86	*50* 13·35± ·92	*50* 21·00±1·48	*50* 22·32±1·58
	Veddahs	*12* 12·28±1·72	*12* 9·56±1·33	*12* 13·95±1·96	*12* 20·71±2·97	*12* 33·44±5·09	*12* 21·13±3·04	*12* 16·90±2·39	*12* 25·57±3·74	*12* 36·48±5·65
	Chimpanzees ...	*18* 19·19±2·24	*18* 18·33±2·13	*18* 24·95±2·97	*9* 10·11±1·62	*9* 39·22±7·13	*18* 20·79±2·44	*18* 25·48±3·05	*18* 43·51±5·74	*9* 41·48±7·65
	Gorillas	*25* 18·56±1·83	*25* 16·00±1·57	*25* 17·91±1·76	*19* 28·40±3·35	*19* 36·98±4·57	*25* 19·19±1·90	*25* 21·07±2·10	*25* 33·40±3·52	*19* 36·91±4·56
	Orang-utans ...	*13* 11·54±1·55	*13* 12·58±1·69	*13* 12·88±1·73	—	—	*13* 16·75±2·28	*13* 18·88±2·59	*13* 25·43±3·57	—

TABLE XV.

Variability Scales for Mesodacryal Characters.*

Subtense				Chord				Arc			
♂		♀		♂		♀		♂		♀	
Egyptians	9·8	Egyptians	11·3	Gaboon (1864)	8·2	Borneo	8·6	Egyptians	6·9	Congo	7·9
English	9·9	English	11·7	Philippines	8·7	—		Gaboon (1880)	7·3	Borneo	8·0
Gaboon (1880)	11·3	Borneo	12·6	Egyptians	9·5	Congo	8·6	Philippines	7·6	—	
Borneo	12·2	*Orangs*	12·9	Javanese	9·7	—		English	7·8	English	9·2
Malays	13·5	—		English	10·0	Gaboon (1880)	9·6	Borneo	8·1	Veddahs	9·6
Gaboon (1864)	13·8	Congo	13·9	Hindoos	10·5	—		Gaboon (1864)	8·8	Gaboon (1880)	10·2
Veddahs	14·1	Veddahs	14·0	Borneo	11·2	English	9·9	Javanese	9·7	—	
Hindoos	14·5	—		Congo	11·3	*Orangs*	11·5	Hindoos	10·3	—	
Congo	16·4	Gaboon (1864)	15·3	Gaboon (1880)	11·7	Veddahs	12·3	Veddahs	11·7	Gaboon (1864)	10·5
Philippines	17·4	—		Veddahs	12·5	Egyptians	12·6	Malays	11·8	—	
Orangs	17·3	—		Malays	12·6	Gaboon (1864)	12·7	Congo	12·4	Egyptians	10·8
Javanese	17·5	Gaboon (1880)	15·8	*Chimpanzees*	14·9	—		*Gorillas*	13·8	*Orangs*	12·6
Gorillas	18·3	*Gorillas*	17·9	*Orangs*	15·2	*Gorillas*	18·6	*Chimpanzees*	15·7	*Gorillas*	16·0
Chimpanzees	23·3	*Chimpanzees*	25·0	*Gorillas*	17·5	*Chimpanzees*	19·2	*Orangs*	16·5	*Chimpanzees*	18·3

* The values for Hylobates are for both sexes together :

Subtense 22·1 | Chord 10·7 | Arc 12·7

For the simotic chord and subtense we have:

TABLE XVI.

Order of Racial Variability for Simotic Characters.*

Simotic Subtense				Simotic Chord			
♂		♀		♂		♀	
Hindoos	21·9	—		Egyptians	16·8	*Chimpanzees*	10·10
Gorillas	22·0	English	18·8	Veddahs	18·4	Egyptians	15·3
English	22·1	Egyptians	22·8	Hindoos	18·6	—	
Veddahs	23·0	Veddahs	33·4	English	18·9	Gaboon (1880)	17·9
Egyptians	23·1	Gaboon (1864)	34·5	*Chimpanzees*	21·9	English	19·9
Gaboon (1880)	29·3	Borneo	36·6	Philippines	22·7	—	
Philippines	31·3	—		Borneo	22·8	Veddahs	20·7
Borneo	32·9	*Gorillas*	37·0	Congo	22·9	Borneo	25·4
Malays	36·3	—		Javanese	23·1	—	
Congo	36·9	Congo	37·3	Malays	24·8	—	
Gaboon (1864)	37·4	Gaboon (1880)	39·2	Gaboon (1864)	28·2	Gaboon (1864)	26·0
Javanese	38·4	—		Gaboon (1880)	28·7	Congo	26·6
Chimpanzees	41·1	*Chimpanzees*	39·2	*Gorillas*	31·1	*Gorillas*	28·4

Again there is practically little to be learnt, the Gorillas are very variable in nasal chord and much less variable (in scale position) on the subtense, while the reverse holds for the Chimpanzees, the subtense being far more variable than the chord. The Negroes are as a rule low down on the scale, being considerably more variable than the English, Egyptians or Hindoos. In 9 cases the female and in 9 the male is more variable in simotic characters.

Lastly we pass to the indices, omitting the calculated mesodacryal subtense index α'. We find for Standard Deviations the order given in Table XVII.

Again there seems little to be learnt with regard to racial variability from these results, beyond the confirmation of what we have learnt from the earlier tables that the Orangs, and the Gorillas as a rule, have large variability; here, however,—as distinguished from the coefficients of variation of the absolute lengths—the Chimpanzee is seen to have very small variability. If, however, we take the coefficients of variation of the indices we find the Chimpanzee is associated with the other two anthropoids of our scales in high variability. Turning to the sexual differences, we find in the apes as many cases (4) of female as of male greater variability; among the human races there are 10 cases in which the female is more variable and 11 cases in which the male is more variable, or again there is little if any distinction of sex in variability.

An examination of Tables XIII and XIV will show the reader that much of the non-significance of the variation scale for racial purposes is quite possibly due

* The values for Hylobates, both sexes together, are: simotic chord 14·5 and simotic arc 57·2.

TABLE XVII.

Order of Standard Deviations of Nasal Bridge Indices.*

Mesodacryal Subtense Index				Mesodacryal Arcual Index				Simotic Index			
♂		♀		♂		♀		♂		♀	
Chimpanzees	5·65	Congo	5·15	*Chimpanzees*	7·13	Congo	6·35	Philippines	6·64	—	
Gaboon (1864)	5·65	*Chimpanzees*	6·05	Philippines	7·68	—		Egyptians	7·27	*Chimpanzees*	7·69
Congo	5·67	Egyptians	6·62	Gaboon (1864)	7·75	Borneo	8·24	Congo	7·64	English	8·09
Malays	6·34	—		Congo	8·67	*Chimpanzees*	9·70	*Chimpanzees*	7·64	Egyptians	8·24
Philippines	6·60	—		Malays	10·55	—		Malays	7·81	—	
Veddahs	7·16	English	6·64	Gaboon (1880)	11·32	English	10·25	Gaboon (1880)	8·81	Gaboon (1864)	8·47
Hindoos	7·23	—		Hindoos	11·46	—		Gaboon (1864)	8·82	Gaboon (1880)	9·38
English	7·47	Borneo	6·94	*Gorillas*	11·56	Gaboon (1864)	11·49	Borneo	9·35	Congo	10·15
Egyptians	7·57	Gaboon (1880)	7·00	English	12·19	Egyptians	11·76	Veddahs	9·77	Borneo	10·15
Gaboon (1880)	7·63	Gaboon (1864)	7·19	Borneo	12·49	Gaboon (1880)	11·84	Hindoos	10·55	—	
Borneo	8·01	*Gorillas*	8·61	Egyptians	13·07	*Gorillas*	14·27	Javanese	11·20	—	
Javanese	8·74	—		Javanese	13·72	—		English	12·21	Veddahs	13·45
Gorillas	9·69	Veddahs	12·52	Veddahs	13·86	Veddahs	18·77	*Gorillas*	22·15	*Gorillas*	20·33
Orangs	18·63	*Orangs*	13·27	*Orangs*	43·04	*Orangs*	34·72	—		—	

* The values for Hylobates, both sexes together, are: Mesodacryal (Subtense) Index 8·7, Mesodacryal (Arcual) Index 10·1, Simotic Index 51·7.

to the smallness of our samples. Except in the case of Egyptians and English, the size of these samples was not under our control; we set out to compare the African and Asiatic anthropoids with the human races of the same environment, and we measured all the crania available, and calculated the variabilities for all series of 10 and over*. Further the homogeneity of some of the series, as the Malay and Javanese, is possibly open to doubt. We have accordingly clubbed together our variation results for the coefficients of variation of the absolute measurements, with the results given in Table XVIII.

TABLE XVIII.

Average Values of Variability of Absolute Measurements on the Nasal Bridge.

With Simotic Lengths			Without Simotic Lengths		
	♂	♀		♂	♀
Chimpanzees ...	23·4	22·4	*Chimpanzees* ...	18·0	20·8
Gorillas ...	20·5	23·6	*Gorillas* ...	16·5	17·5
Orangs ...	—	—	*Orangs* ...	16·3	12·3
[*Hylobates* ♂ + ♀ 23·4]			[*Hylobates* ♂ + ♀ 15·1]		
Mean 22·5 †			*Mean 16·9*†		
Malays ...	19·8	—	Malays ...	12·6	—
Javanese ...	19·7	—	Javanese ...	12·3	—
Mean 19·8			*Mean 12·5*		
Congo	20·0	18·9	Congo	13·5	10·1
Gaboon (1864)	19·3	19·8	Gaboon (1864)	10·3	12·9
Gaboon (1880)	17·6	18·5	Gaboon (1880)	10·1	11·9
Mean 19·0			*Mean 11·5*		
Philippines ...	17·5	—	Philippines ...	11·2	—
Borneo... ...	17·4	18·2	Borneo... ...	10·5	9·7
Mean 17·7			*Mean 10·5*		
Veddahs ...	15·9	18·0	Veddahs ...	12·7	11·9
Hindoos ...	15·2	—	Hindoos ...	11·7	—
Mean 16·4			*Mean 12·1*		
Egyptians ...	13·2	14·6	Egyptians ...	8·7	11·5
English ...	13·7	13·9	English ...	9·3	10·3
Mean 13·8			*Mean 10·0*		
General Means	*17·9*	*18·7*	*General Means*	*12·5*	*12·9*

* Nubians excepted: these were included at a later date.

† Hylobates not included.

Whether we take the number of cases in which the female is more variable than the male—i.e. 7 out of 9 in the first series and 6 out of 10 in the second—or the mean variabilities of the whole series, we see that the female is certainly not less variable than the male.

Massed as above the table seems to show more racial relationship to variability. The races group better together, and generally speaking—Veddahs, perhaps, excepted—there is decreasing variability as we reach higher degrees of civilisation, i.e. as we pass from the Apes through East Asiatics and Negroes to Hindoo, Ancient Egyptian and English. It is as well to see if these results correspond with those for the two mesodacryal and the simotic indices.

It will be seen in the first place that these results (Table XIX) confirm those of the previous table (XVIII) for the variation of the absolute lengths, in that

TABLE XIX.

Average Values of Variability of Indices of Nasal Bridge (α, β *and* S)

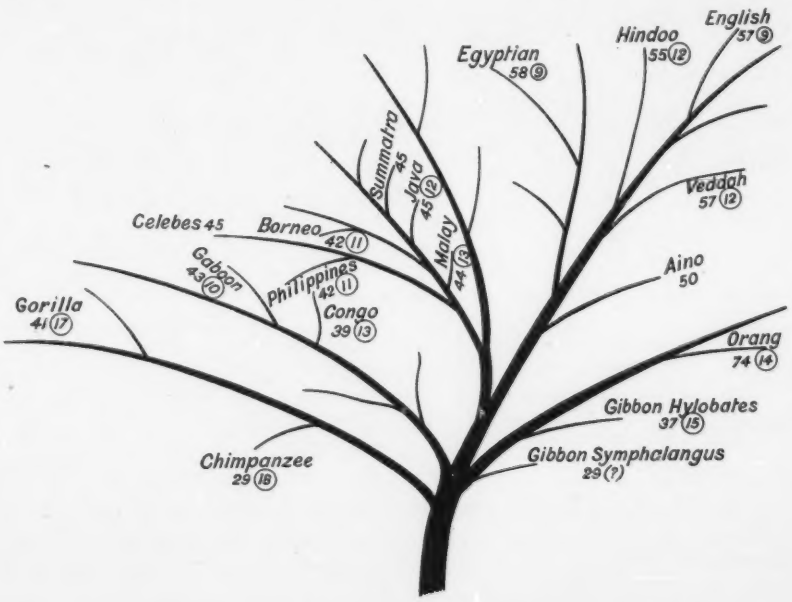
From Standard Deviations			From Coefficients of Variation		
	♂	♀		♂	♀
Chimpanzees ...	6·8	7·8	*Chimpanzees* ...	29·2	35·3
Gorillas ...	14·5	14·4	*Gorillas* ...	31·5	29·8
Orangs ...	30·8	24·0	*Orangs* ...	30·0	21·1
[*Hylobates* ♂ + ♀ 9·9]			[*Hylobates* ♂ + ♀ 30·4]		
Mean 16·4 *			*Mean 29·5* *		
Malays ...	8·2	—	Malays ...	20·8	—
Javanese ...	11·2	—	Javanese ...	27·5	—
Mean 9·7			*Mean 24·2*		
Congo	7·3	7·2	Congo	22·9	24·3
Gaboon (1864)	7·4	9·1	Gaboon (1864)	20·4	24·8
Gaboon (1880)	9·3	9·4	Gaboon (1880)	25·0	28·3
Mean 8·3			*Mean 24·3*		
Philippines ...	7·0	—	Philippines ...	19·2	—
Borneo... ...	10·0	8·4	Borneo... ...	28·5	21·9
Mean 8·5			*Mean 23·2*		
Veddahs ...	10·3	14·9	Veddahs ...	18·4	27·7
Hindoos ...	9·7	—	Hindoos ...	18·5	—
Mean 11·6			*Mean 21·5*		
Egyptians ...	9·3	8·9	Egyptians ...	16·5	18·6
English ...	10·6	8·3	English ...	18·9	16·3
Mean 9·3			*Mean 17·6*		
General Means	*10·9*	*11·2*	*General Means*	*23·4*	*24·8*

* Hylobates not included.

they make the female slightly more variable on the average than the male. For the standard deviations the male is more variable in 6 out of 10 cases; for the coefficients of variation the female is more variable in 6 out of 10 cases. In either method of measurement the apes are more variable than men, with the one exception of the Chimpanzees in the case of the standard deviations, where the small variation is associated with small variation in the Negro group.

(8) *Racial Relationship as based on Nasal Bridge Measurements.*

Having general regard to Tables XV—XIX for variability, and comparing the orders therein with those for the racial order of absolute lengths, it seems impossible to suggest any *linear* scale of arrangement which will mark racial relationship; it is impossible to assert that the Negroes or the East Asiatic group stand regularly higher or lower in a *linear* scale. Still there does appear to be some order in the scales both for absolute mesodacryal values and for variabilities. Thus the Veddah nasal bridge is more closely related to that of the Orang than the latter's to the Negro group, which on the whole is closer to that of the African apes. Our numbers are too small, our probable errors too large, for insistance on any individual point, but the measurements lead to constants both for index and variability suggesting a scheme of the following type:



Tree. Mesodacryal Subtense Index and Average Variability for ♂'s indicated.

On this tree we have placed the mean values of the mesodacryal subtense index (α) and the average variability of the mesodacryal lengths*, both for males to indicate the degree of correspondence suggested.

In such a tree as this we see the general tendency of the higher races to have (1) a more developed nasal bridge, and (2) a markedly lessened variability. The tree is merely diagrammatic and no great stress is of course laid on it, but it does suggest that the results reached both for mean values and variabilities may not be merely contradictory, but correspond to a real evolutionary order in the development of the nasal bridge.

(9) *On the Correlations of the Nasal Bridge Characters.*

The correlations of the two mesodacryal indices and the simotic index are given in Table XX.

TABLE XX.

Coefficients of Correlation. Nasal Bridge Indices.

	$r_{\alpha\beta}$		$r_{\alpha\alpha'}$		$r_{S\alpha}$	
	♂	♀	♂	♀	♂	♀
Congo	*50* ·881 ± ·021	*27* ·864 ± ·033	*50* ·882 ± ·021	*27* ·867 ± ·032	*50* ·613 ± ·060	*25* ·704 ± ·068
Gaboon, 1864	*48* ·904 ± ·018	*37* ·941 ± ·013	*48* ·905 ± ·018	*37* ·945 ± ·012	*47* ·258 ± ·092	*35* ·509 ± ·084
Gaboon, 1880	*16* ·976 ± ·008	*18* ·959 ± ·013	*16* ·978 ± ·007	*18* ·959 ± ·013	*16* ·423 ± ·138	*18* ·508 ± ·118
Philippine Islands ...	*17* ·725 ± ·078	—	*17* ·727 ± ·077	—	*17* ·374 ± ·141	—
Borneo	*26* ·948 ± ·013	—	*26* ·945 ± ·014	—	*26* ·426 ± ·108	—
Java and Madura ...	*39* ·940 ± ·013	—	*39* ·944 ± ·012	—	*39* ·318 ± ·097	—
Mixed "Malays" ...	—	*24* ·897 ± ·027	—	*24* ·897 ± ·027	—	*23* ·696 ± ·073
Hindoos	*10* ·929 ± ·029	—	*10* ·931 ± ·028	—	*10* ·891 ± ·044	—
English	*50* ·955 ± ·008	*50* ·961 ± ·007	*50* ·956 ± ·008	*50* ·962 ± ·007	*50* ·440 ± ·077	*50* ·519 ± ·070
Egyptians	*50* ·976 ± ·005	*50* ·964 ± ·007	*50* ·975 ± ·005	*50* ·964 ± ·007	*50* ·444 ± ·077	*50* ·471 ± ·074
Veddahs	*15* ·959 ± ·014	*12* ·971 ± ·011	*15* ·958 ± ·014	*12* ·972 ± ·011	*15* ·291 ± ·159	*12* ·369 ± ·168
Chimpanzees	*33* ·675 ± ·064	*18* ·782 ± ·062	*33* ·674 ± ·064	*18* ·784 ± ·061	*13* ·062 ± ·186	—
Gorillas	*27* ·889 ± ·027	*25* ·928 ± ·019	*27* ·888 ± ·027	*25* ·924 ± ·020	*21* ·740 ± ·067	*19* ·464 ± ·121
Orang-utans	*44* ·839 ± ·030	*13* ·720 ± ·090	*44* ·844 ± ·029	*13* ·715 ± ·091	—	—
Gibbons, Hylobates ♂ + ♀	*25* ·812 ± ·046		*25* ·815 ± ·045		*16* ·199 ± ·162	

We have already (see pp. 399—401) discussed the relation of α to α' and seen that it does not lead us to any very marked racial order. The correlation of the two mesodacryal indices gives a somewhat clearer result, if we group the correlations thus:

* Coefficients of variation of arc, chord and subtense.

$r_{\alpha\beta}$ in Groups.

	♂	♀
Apes	·801	·810
East Asiatics ...	·871	·897
Negroes	·920	·931
Veddahs	·959	·971
Hindoos	·929	—
Egyptians } English } ...	·965	·962
All values, means	·892	·899

The suggestion is that there is increased correlation with higher civilisation, the Veddahs being somewhat out of rule. The females are slightly, but very probably not significantly, more highly correlated than the males. There is nothing out of keeping in this correlation order with that for the means and variations exhibited in the "tree" on p. 417, but it is too slender to give it much support. If we turn to the correlations of simotic and mesodacryal (subtense) indices r_{Sa} we find a greater range of variation and thus more possibility of getting an order of some racial interest.

r_{Sa}. Correlation Order.

	♂	♀
Chimpanzees ...	·06	—
[*Hylobates* ...	·20 (♂ + ♀)	—]
Gaboon, 1864 ...	·26	·51
Veddahs	·29	·37
Javanese... ...	·32	—
Philippines ...	·37	—
Gaboon, 1880 ...	·42	·51
Borneo	·43	—
Malays	—	·70
English	·44	·52
Egyptians ...	·44	·47
Congo	·61	·70
Gorillas	·74	·46
Means	·40	·53

With the single exception of the Gorilla the females have in every case, and often markedly, more correlation than the males. But the results are extremely irregular, even if we allow for the small numbers dealt with. Accordingly it seemed worth while to deal more at length with the relation between the simotic and mesodacryal characters, and further correlations were worked out. It must

be borne in mind that the mesodacryal subtense consists of two portions, the first part due to the nasal bones is the simotic subtense, the second part is due to the maxillary bones. If we subtract the simotic subtense from the mesodacryal subtense $(DS)-(SS)$, we have a measure of the part of the nose due solely to the maxillary bones, and we may correlate this with (SS) the part due to the nasal bones. There will be no spurious correlation in this as in correlating (DS) and (SS) directly. Further we may form an index $\{(DS)-(SS)\}/(DC)$ and correlate this with the simotic index $(SS)/(SC)$, although in doing this (SC) must be considered in a certain sense as contained in (DC). The spurious correlation, however, is unlikely to be as great in this as in (SS) and (DS), for the maxillary walls of the nose can approach so close that there is no (SC) at all, as in the case of many Orangs and in some Negro skulls*.

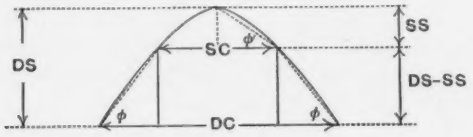


Fig. (i).

(10) *The Maxillary and Simotic Nasal Angles, ϕ and ϕ'.*

The value of $DC-SC$ may be used to obtain a measure of the flatness of the maxillary walls of the nose. Clearly (see figure above)

$$\tan\phi=(DS-SS)/\tfrac{1}{2}(DC-SC).$$

We term ϕ the maxillary nasal angle and its complement $90^\circ-\phi$ measures approximately the angle the maxillary wall of the nose makes with the median plane of the skull. Table XXI records the values of the nasal maxillary angle ϕ for the races dealt with; they are obtained not from the calculation of ϕ from individual crania, but by the rougher process of using the mean values of the mesodacryal and simotic subtenses and chord in the above formula†. The table emphasises again the relation of the Veddahs and the higher races to Orang and Hylobates, while it indicates the relation of the Negro races to the African anthropoids. At some points the female order is not in accord with the male, but the smallness of many of the series dealt with seems sufficient to explain the source of these differences. Some races have clearly a marked sexual difference, but it is not always one way and the means show no very great difference; more data and longer series would be needful to be certain of a persistent sexual differentiation.

* E.g. Gaboon 1864, Nos. 10, 11, 81, and Congo 70: see *Biometrika*, Vol. VIII. p. 319, and see especially the remarks in Tables of measurements. In one gibbon the simotic subtense was actually negative or the nasal bones depressed.

† Table XXIV A gives the values of ϕ and their variabilities for a small number of selected races. It will be seen that the differences due to the two methods are not great. The short method will give results close enough for any conclusions which are in the least likely to be drawn from such small series.

TABLE XXI.

Maxillary Nasal Angle ϕ.

♂		♀	
Orang-utans	55·3°	*Orang-utans*	57·5°
Egyptians	54·3°	Veddahs	56·1°
Veddahs	53·8°	Egyptians	54·3°
[*Hylobates* (♂ + ♀)	52·5°]	[*Hylobates* (♂ + ♀)	52·5°]
Hindoos	52·0°	Gaboon, 1880	50·3°
Nubians	51·3°	English	49·3°
Sumatra	51·3°	Philippines	49·0°
English	50·8°	—	—
Ainos	47·6°	—	—
Moluccas	47·0°	—	—
Celebes	46·9°	Gaboon, 1864	48·5°
Javanese	46·0°	—	—
Gaboon, 1864	45·7°	Hindoos	48·4°
Gaboon, 1880	45·2°	Nubians	48·2°
Malays	44·7°	—	—
Philippines	44·6°	Javanese	44·8°
Borneo	44·4°	Congo	42·5°
Congo	44·1°	[*Symphalangus*	42·3°]
[*Symphalangus* (♂ + ♀)	42·3°]	Borneo	42·0°
Gorillas	35·1°	*Gorillas*	39·1°
Chimpanzees	34·8°	*Chimpanzees*	37·8°
Mean	47·1°	Mean	47·7°

The smaller ϕ, the flatter the maxillary part of nasal bridge.

If we now turn to Table XXII we find a number of additional correlations, which are sufficiently interesting to make one appreciate how much more valuable they would have been had we had longer series and more variety of races available. We have first correlated the mesodacryal and simotic portions, $DS - SS$ and SS, of the whole subtense of the nasal bridge. In every case dealt with, male and female, these subtenses are *negatively* correlated. On the other hand the correlation of the mesodacryal subtense with the simotic subtense is always positive and often substantial*. This positive correlation is therefore due to the appearance of SS in both variates, i.e. it is a spurious correlation. Actually when the maxillary part of the nasal bridge is larger, then the simotic part is smaller. Intraracially—that is among individuals of the same race—there is a compensatory growth of the nasal bridge and those who develop large nasal bones have a smaller maxillary nasal development. This point seems to us of very great importance; the tendency now-a-days is to insist on the importance of anatomical unities. This has largely arisen from two sources. In the first place craniology

* For the mesodacryal subtense with the simotic subtense, all the correlations except that for the male Chimpanzee are positive and often substantial, the intraracial correlation amounting to +·34 to +·38. Further the interracial correlation is high indeed, being +·81 to +·87. But as we see these results are in part spurious.

TABLE XXII.

Additional Correlations. Nasal Bridge Characters.

	$r_{DS,\ SS}$		$r_{DS-SS,\ SS}$		$r_{\frac{DS-SS}{DC},\ \frac{SS}{SC}}$		$r_{DC,\ SC}$		$r_{DC-SC,\ SC}$	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Congo	+·467±·075	+·632±·081	−·143±·093	−·138±·109	−·074±·095	+·092±·134	+·275±·088	+·217±·129	−·501±·071	−·729±·063
Gaboon, 1864 ...	+·295±·090	+·437±·092	−·487±·075	−·207±·109	−·229±·093	+·026±·114	+·345±·087	+·536±·081	−·745±·044	−·387±·097
Java and Madura	+·658±·061	—	−·035±·108	—	−·165±·105	—	+·266±·100	—	−·589±·071	—
English	+·355±·083	+·505±·071	−·480±·073	−·130±·094	−·102±·094	+·274±·088	+·446±·076	+·611±·060	−·386±·081	−·328±·085
Egyptians ...	+·416±·079	+·230±·090	−·457±·075	−·465±·075	−·132±·094	−·169±·093	+·172±·093	+·520±·070	−·571±·064	−·138±·094
Gorillas	+·327±·131	+·120±·153	−·138±·144	−·468±·121	+·624±·090	−·079±·154	+·512±·109	+·303±·141	−·107±·146	−·137±·152
Chimpanzees ...	−·153±·183	+·364±·195	−·587±·123	−·042±·224	−·377±·161	−·079±·223	−·039±·187	+·425±·184	−·613±·117	+·222±·214
[*Hylobates* ...	+·116±·166	for ♂ + ♀	−·220±·161	for ♂ + ♀	−·112±·166	for ♂ + ♀	−·195±·162	for ♂ + ♀	−·730±·079	for ♂ + ♀]
Interracial (omitting *Orangs*)	+·868±·039	+·806±·066	+·581±·105	+·501±·140	+·370±·137	+·393±·158	+·344±·140	+·612±·117	−·413±·132	−·332±·167
Intraracial mean*	+·338	+·381	−·333	−·226	−·065	+·011	+·283	+·435	−·502	−·250

* *Hylobates* excluded.

has been chiefly in the hands of the pure anatomist rather than in those of the student of philosophical evolution. The former has insisted on the importance of growth centres and anatomical unity of measurement; he has usually no appreciation of the relatively high correlations of the parts of the bony structure. He is thus liable to overlook the fact that from the standpoint of evolution a complex anatomical organ may be of far more importance to the race and to the individual than one factor of it which may be an anatomical unity. In the second place Mendelism has become the mode, and to surmount difficulties about characters which do not "mendelise," it has been customary to assert that they consist of a complex of simple Mendelian units*. On the original Mendelian theory such "units" were asserted to be independent, although as such a theory was found to be unworkable, a crude theory of "coupling," as a measurable association of anatomically or physiologically simple unities, was evolved to cover the real facts of correlation. In this manner there has arisen a conscious or unconscious association of anatomical and Mendelian units, and it has been supposed that an anatomical unity would be more likely to "mendelise" than a combination of such unities—a single bone like the femur than a measurement like the leg length or the stature. The present result seems an illustration of the futility of neglecting the correlation of characters or treating them as compounded of independent Mendelian or even anatomical unities. The bridge of the nose consists of parts which are distinct anatomical unities, but the evolutionary factor is probably far better represented by the physiognomic factor—the whole bridge of the nose—than by any anatomical unit. When one part exceeds there is a correlated defect in the other part, and this rule extends practically through all the races examined. It is thus quite conceivable that a single measurement like the sagittal arc is from the evolutionary standpoint far more important than any of the simple arcs—opisthion to lambda, lambda to bregma, and bregma to nasion—into which we may reduce it by aiming at the measurement of anatomical unities. There is such a thing as an evolutionary factor, a determinant which controls the development of a whole series of anatomical unities, and the heredity brought into evidence by such a factor may be far more important from the standpoint of evolution than the heredity of any simple anatomical character. What group of anatomical units go to form any such determinant can only be appreciated by a thorough study of the correlations of simple anatomical parts.

Especially in the nasal bridge is this matter of very great importance, for while within the race an individual with small maxillary height ($DS - SS$) has a large simotic height (SS), *interracially* this is no longer true, the race with a small maxillary height will have a small simotic height and the positive correlation interracially is very substantial (+·581)—this must be compared with the mean intraracial correlation which is −·333. Both these results are for males, for females the numbers are +·501 and −·226 respectively. This reversal of sign

* Of course when it is convenient a vast congeries of factors, such as "Albinism" or "Jewishness," are illogically treated as a simple Mendelian "unit"!

when we pass from intraracial to interracial correlations is a thing previously not unknown. Thus in 1903 in a paper* on interracial and intraracial correlations, Jacob, Lee and Pearson showed that while with individuals a long cranium is likely to be a broad cranium, yet interracially a compensating factor comes in, a long-headed race is likely to be a narrow-headed race. Thus it is quite conceivable that capacity of the cranium—depending on many anatomical units—may be of far more evolutionary importance than the measure of any single "anatomical unit" of the skull. We have referred at length to these matters here, because there is a growing idea—fostered probably by the idea of Mendelian "units," that the measurement of "anatomical units"—or the measurement between "anatomical points"—is of primary importance in craniology. Whether craniologists measure the *same* thing or not is immensely important, the correlation between anatomical units is also of great value as determining what combinations of simple units form evolutionary factors. But very little service is done by insisting too largely on anatomical unity in and for itself. Evolution depends largely on physiological fitness, and organs of physiological importance are rarely compounded of either single anatomical or of single Mendelian units.

If we now turn to the index correlations of $(DS - SS)/DC$—i.e. height of maxillary portion of nose by its breadth—with SS/SC—i.e. height of nasal bones portion by its breadth—our results are less uniform. Putting the male Gorillas on one side for a moment there are only two of the correlations which can be said to be significant, namely, possibly the male Chimpanzee and the female English, and these are of opposite signs. The means for male races and for female races are $-\cdot065$ and $+\cdot011$, and these would be of no service for prediction. With regard to the Gorilla result, this arises principally from three males with the very high simotic indices of 88, 106 and 103. It is conceivable that the material is not really homogeneous; the arithmetic has been carefully repeated without change in values. If we take these indices to measure the cuneal or wedge-shaped properties of the two portions of the nose, we should say that individually there is very little relation between the ratio of height to breadth in the simotic and maxillary portions of the nasal bridge; the only exception to this rule being the male Gorilla. On the other hand the cuneal characters are *positively* and sensibly correlated ($+\cdot370$ to $+\cdot393$) interracially, an obtuso-cuneal nasal part being also associated with an obtuso-cuneal maxillary part and an acuto-cuneal nasal part with an acuto-cuneal maxillary part.

We have already discussed the maxillary nasal angle ϕ, the complement of which roughly measures the angle between the maxillary wall of the nose at the bridge and the sagittal plane of the skull. We can introduce a similar angle ϕ' to measure roughly the angle between the nasal bone and the simotic chord. We may take (see Fig. (i), p. 420):

$$\tan \phi' = SS/(\tfrac{1}{2}SC)$$
$$= 2 \text{ Simotic Index.}$$

* *Biometrika*, Vol. II. p. 355. For the first introduction of the ideas of *intraracial* and *interracial* correlation, see *Biometrika*, Vol. I. p. 460.

It will be of interest to investigate whether the correlations of ϕ and ϕ' are higher than those of the cuneal indices. The following table* (XXIII) gives the

TABLE XXIII.* *Simotic Nasal Angle ϕ'.*

♂		♀	
Gorillas	48·6°	*Gorillas*	47·8°
English	45·5°	English	43·0°
Hindoos	41·8°	Hindoos	38·0°
Egyptians	41·6°	Egyptians	36·5°
Veddahs	41·1°	Veddahs	36·4°
Ainos	40·9°	—	—
Nubians	34·3°	Borneo	34°8°
Javanese	34·1°	Javanese	33·2°
Malays	34·0°	—	—
Gaboon, 1864	31·7°	Philippines	30·1°
Philippines	31·3°	Gaboon, 1864	29·0°
Borneo	31·1°	Congo	27·2°
Celebes	30·7°	—	—
Sumatra	30·3°	—	—
Gaboon, 1880	30·1°	Nubians	25·2°
Moluccas	28·0°	—	—
Congo	27·1°	Gaboon, 1880	24·6°
Chimpanzees	23·2°	*Chimpanzees*	20·3°
†*Symphalangus*	11·5°	†*Symphalangus*	11·5°
†*Hylobates*	9·8°	†*Hylobates*	9·8°
Mean	32·3°	Mean	29·8°

The smaller ϕ' the flatter the simotic portion of the nasal bridge, i.e. the greater the simosis.

TABLE XXIV A. *Maxillary Nasal Angle ϕ. Mean and Variability.*

	Male			Female		
	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
Egyptians ...	54·33± ·57	5·97± ·40	10·99± ·75	54·29± ·53	5·56± ·37	10·24± ·70
[*Hylobates* (♂ + ♀)	53·06±1·50	8·90±1·06	16·78±2·06]	—	—	—
English	50·63± ·55	5·74± ·39	11·35± ·78	49·15± ·48	5·00± ·34	10·17± ·69
Javanese	46·06± ·91	8·43± ·64	18·31±1·44	—	—	—
Gaboon, 1864 ...	45·94± ·53	5·34± ·37	11·63± ·82	49·19± ·64	5·62± ·45	11·43± ·93
Congo	44·13± ·53	5·52± ·37	12·50± ·86	43·30± ·71	5·27± ·50	12·16±1·18
Gorillas	36·12± ·96	6·56± ·68	18·15±1·95	39·92±1·10	7·11± ·78	17·82±2·01
Chimpanzees ...	35·96±1·80	9·61±1·27	26·74±3·78	34·39±1·82	8·12±1·29	23·60±3·96

* These values of ϕ' are calculated from the mean racial simotic index. In Table XXIV B the mean value of ϕ' as obtained from averaging the simotic angles of the individual members of the race is given for a few races as well as the variabilities for these selected races. The agreement of the directly and indirectly calculated means is quite reasonable.

† Both sexes together.

interracial values of ϕ'. It will be seen of course that the order must be the same as that of the simotic index, but if we compare this table with Table XXI some interesting points arise as we shall show in the next section. Tables XXIV A and XXIV B give the means and variabilities of the maxillary and simotic angles ϕ and ϕ'.

TABLE XXIV B.

Simotic Nasal Angle ϕ'. Mean and Variability.

	Male			Female		
	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
Egyptians ...	41·25 ± ·45	4·70 ± ·32	11·40 ± ·78	35·97 ± ·57	6·02 ± ·41	16·73 ± 1·16
[*Hylobates* (♂ + ♀)	9·75 ± ·84	4·97 ± ·59	50·99 ± 7·50]	—	—	—
English	44·70 ± ·63	6·58 ± ·44	14·73 ± 1·01	42·58 ± ·47	4·96 ± ·33	11·65 ± ·80
Javanese	33·23 ± ·88	8·15 ± ·62	24·54 ± 1·98	—	—	—
Gaboon, 1864 ...	31·15 ± ·72	7·34 ± ·51	23·56 ± 1·73	28·46 ± ·85	7·42 ± ·60	26·08 ± 2·24
Congo	26·62 ± ·73	7·68 ± ·52	28·86 ± 2·10	26·48 ± 1·20	8·91 ± ·85	33·63 ± 3·55
Gorillas	46·48 ± 1·52	10·30 ± 1·07	22·16 ± 2·42	45·63 ± 1·74	11·23 ± 1·23	24·61 ± 2·85
Chimpanzees ...	22·77 ± 1·37	7·31 ± ·97	32·10 ± 4·66	20·00 ± 1·73	7·70 ± 1·22	38·51 ± 6·97

It would appear from Tables XXI and XXIII that ϕ' has a greater interracial range and from Tables XXIV A and B that it has a greater intraracial variability than ϕ. What we need for a good racial character is a great interracial range and a small intraracial variability. We cannot therefore say that ϕ' is a better racial character than ϕ.

(11) *General Classification of Nasal Bridges by ϕ and ϕ'*.*

We need some new terms. We propose to term races which have high values or low values of both ϕ and ϕ' *homoclinic*, while those which have low values of one and high of the other are *heteroclinic*. Among apes the Gorilla is markedly heteroclinic, and Hylobates is the same, but in the opposite direction. The Chimpanzee and Symphalangus are both homoclinic and so are the English, Egyptians, Hindoos and Veddahs.

Without regard to the exact numerical values and as merely descriptive terms the following types of Gephyrosis will indicate the nature of the characterisation, where it must be remembered that the reader has to fix his attention on the

* Professor G. D. Thane has kindly made the following suggestions for a more complete angle nomenclature of the nasal bridge (see Fig. (i), p. 420):

Lateral simotic angle = our simotic nasal angle ϕ'.

Mesial simotic angle = our $90° - \phi'$ = angle between simotic chord and median plane.

Simotic angle (median) = our $180° - 2\phi'$ = internal angle between two simotic chords.

Lateral maxillary angle = our ϕ = maxillary nasal angle.

Maxilli-simotic angle = our $180° - \phi + \phi'$ = internal angle between simotic and maxillary chords.

The most important point here is the maxilli-simotic angle, the approach of which to 180°, i.e. the

lower parts of the "bridge" from its "springings" at the dacrya to the strokes marking the naso-maxillary sutures.

14	23	27	34	22
Hyperplatygephyreal	*Platygephyreal*	*Mesogephyreal*	*Leptogephyreal*	*Hypoleptogephyreal* (approaching *Orthogephyreal*)

FIG. (ii). *Types of Gephyrosis.*

Similarly we have for the part of the "bridge" from "haunch" to "haunch," i.e. the nasal bones, or part between the strokes marking the naso-maxillary sutures, the following characterisation:

15	8	10	29	13
Hypersimotic	*Simotic*	*Mesotic*	*Stenotic*	*Hypostenotic*

FIG. (iii). *Types of Simosis.*

For classificatory purposes it may be useful to divide ϕ into three classes: when ϕ is under 46°, the group shall be called *platygephyreal,* when ϕ lies between 46° and 51°, the group is *mesogephyreal,* and when ϕ is over 51°, the equality of ϕ and ϕ', marks the "triangularity" of the bridge, or the unbroken character of the nasal wall.

Maxilli-simotic angle $180° - \phi + \phi'$.

♂		♀	
Gorillas	193·5°	*Gorillas*	188·7°
English	174·7°	English	173·7°
Ainos	173·3°	—	—
Hindoos	169·8°	Borneo	172·8°
Malays	169·3°	—	—
Chimpanzees	168·4°	Hindoos	169·6°
Javanese	168·1°	Javanese	168·4°
Veddahs	167·3°	Congo	164·7°
Egyptians	167·3°	*Chimpanzees*	162·5°
Borneo	166·7°	Egyptians	162·2°
Philippines	166·7°	Philippines	161·1°
Gaboon (1864)	166·0°	Gaboon (1864)	160·5°
Gaboon (1880)	164·9°	Veddahs	160·3°
Celebes	163·8°	—	—
Congo	163·0°	Nubians	157·0°
Nubians	163·0°	Gaboon (1880)	154·3°
Moluccas	161·0°	—	—
Sumatra	159·0°	—	—
Symphalangus	149·2°	*Symphalangus*	149·2°
Hylobates	137·3°	*Hylobates*	137·3°

Only the Gorillas have a re-entrant racial maxilli-simotic angle, although such angles occur in individual cases of other races. Of the races considered the English appear to have most nearly an unbroken nasal wall. The racial order is not clearly marked as Negroes and Asiatics are much intermixed.

TYPES OF THE NASAL BRIDGE.

1 **2** **1 *bis*** **2 *bis***

Dog. Nasal Bridge. Dog. Muzzle Section.

1—2 *bis* = Hypersimotic Platygephyrosis.

3 Chimpanzee. **4** Chimpanzee. **5** Symphalangus.

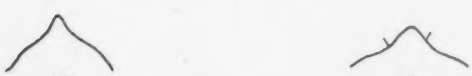
6 **7** **8** **9**

Congo Negroes. Gaboon Negroes.

3—9 = Simotic Platygephyrosis.

10 Malay. **11** Malay. **12** Malay.

10—12 = Mesotic Platygephyrosis.



13 Gorilla. **14** Gorilla.

13—14 = Stenotic Platygephyrosis.

It has not always been possible to select a nasal bridge with the mean values of both ϕ and ϕ', and the typical form will hardly be realised even from two or three cases.

TYPES OF THE NASAL BRIDGE.

15
Hylobates.

16
Hylobates.

17
Hylobates.

18
Orang-utan.

15 = Hypersimotic Mesogephyrosis. 16—17 = Simotic Leptogephyrosis. 18 = Simotic Leptogephyrosis.

19

20

Natives of Moluccas.
19—20 = Simotic Mesogephyrosis.

21

22

Natives of Sumatra.
21—22 = Simotic Leptogephyrosis.

23
Aino.

24
Aino (Variant).

23—24 = Mesotic Mesogephyrosis.

25
Nubian.

26
Nubian (Variant).

25—26 = Mesotic Leptogephyrosis.

27
English.

29
Veddah.

31
Egyptian.

33
Hindoo.

28
English.

30
Veddah.

32
Egyptian.

34
Hindoo.

27—28 = Stenotic Mesogephyrosis. 29—34 = Stenotic Leptogephyrosis.

It has not always been possible to select a nasal bridge with the mean values of both ϕ and ϕ', and the typical form will hardly be realised even from two or three cases.

group is *leptogephyreal.* In the same way the simotic nasal angle ϕ' may be classed as *simotic* when under 32°, *mesotic* between 32° and 41°, and *stenotic* when over 41°. These limits should all be reduced by about 2° in classifying the female simotic nasal angle, which differs sexually by at least this amount from the male. We have accordingly the following table, of which we give illustrations to indicate the type. The diagonal from simotic platygephyrosis to

TABLE XXV.

Value of Maxillary Nasal Angle ϕ.

Value of Simotic Nasal Angle ϕ'.	Under 46°	46° to 51°	Over 51°
Under 32°	Simotic Platygephyrosis e.g. *Chimpanzees* and Negroes	Simotic Mesogephyrosis e.g. Natives of Moluccas	Simotic Leptogephyrosis e.g. *Hylobates* and natives of Sumatra
32° to 41°	Mesotic Platygephyrosis e.g. Malays	Mesotic Mesogephyrosis e.g. Ainos	Mesotic Leptogephyrosis e.g. Nubians
Over 41°	Stenotic Platygephyrosis e.g. *Gorillas*	Stenotic Mesogephyrosis e.g. English	Stenotic Leptogephyrosis e.g. Egyptians and Hindoos

stenotic plagygephyrosis marks the homoclinic groups. The simotic leptogephyrosis of the smaller gibbon and the stenotic platygephyrosis of the gorilla mark the heteroclinic extremes, which weaken the interracial correlation of ϕ and ϕ'. Table XXVI gives the values of $r_{\phi\phi'}$.

With the exception of the Gorilla, which is as in the case of the cuneal indices (p. 424) again anomalous, we see that there is *intraracially* a small *negative* correlation between flatness of the maxillary and flatness of the nasal bones. But *interracially* it is otherwise; there is quite a moderate degree of positive correlation and a flat nasal part of the bridge is found in the same races as a flat maxillary part. This is another instance of the reversal of intraracial by interracial correlation.

(12) *Discussion of Projections of Nasal and Maxillary Portions of Nose on the Base of the Nasal Bridge.*

Having studied the relation of the subtenses, the indices and the angles, we now turn to the chords. The mesodacryal chord is positively correlated with the simotic chord for all races except male Chimpanzees and the mixed data for Hylobates, but in both these cases the correlations are insignificant having regard to their probable errors; see Table XXII, p. 422. Both interracially and intraracially a broad maxillary

TABLE XXVI.

Correlation of Maxillary and Simotic Nasal Angles ϕ and ϕ'.

	♂	♀
Congo	−·037±·095	−·127±·133
Gaboon, 1864 ...	−·338±·087	−·095±·113
Javanese	−·054±·108	—
English	−·169±·093	−·005±·095
Egyptians	+·053±·095	−·183±·092
Gorillas	+·447±·118	−·217±·147
Chimpanzees	−·329±·167	−·247±·211
[*Hylobates* (♂+♀) ...	−·058±·168	−·058±·168]
Intraracial Mean ...	−·061	−·146
Interracial Value* ...	+·353±·139	+·220±·178

portion of the nose would thus signify a broad simotic portion. But the whole result is, as that for the subtenses, spurious and arises from the simotic portion recurring in the mesodacryal chord. If we subtract the simotic chord from the mesodacryal then the difference $(DC-SC)$ is *negatively* correlated with the simotic chord SC, and the correlation is fairly substantial both interracially and intraracially. In other words, whenever a race or an individual is found for which the nasal bones have a big projection on the base of the nasal bridge, then the maxillary bones have a small projection, and *vice versâ*. Thus individually and racially a principle of compensation appears at work. Now we have seen that intraracially ϕ is negatively correlated with ϕ', or a steep maxillary portion is associated in the individual with a flat nasal bone portion of the bridge. Thus intraracially it is conceivable that even if the breadth of the nasal bone and the breadth of the maxillary wall of the nose were positively correlated, the projections might well be of opposite signs. But we cannot use this explanation to account for the negative interracial correlation of the projections, for here the maxillary and simotic nasal angles are positively correlated. In the case of intraracial correlations not only are the projections $\frac{1}{2}SC$ and $\frac{1}{2}(DC-SC)$ negatively correlated but also the subtenses SS and $(DS-SS)$. Thus it is not improbable that in the individual a small nasal bone is associated with a large maxillary wall of the nose—a feature we may speak of as the Orang-utan character. But this does not hold interracially, for the subtenses SS and $(DS-SS)$ are *positively* correlated (Table XXII) and substantially so for both sexes. It is of some interest to consider whether interracially the nasal bone and the maxillary wall of the nose are

* *Hylobates* excluded.

positively correlated. In order to test this point a little more definitely, let us suppose *SB* to be the breadth of a nasal bone and *DB* the breadth of the maxillary wall at the bridge. *Approximately*:

$$SB = \sqrt{\tfrac{1}{4}(SC)^2 + (SS)^2} = (SS)/\sin\phi',$$

$$DB = \sqrt{\tfrac{1}{4}(DC - SC)^2 + (DS - SS)^2} = (DS - SS)/\sin\phi.$$

Table XXVII gives the values of *SB* and *DB* found for each race from the means of that race for *SC*, *SS*, *DC* and *DS*. Of course the nasal bone and the

TABLE XXVII.

Calculated Values of SB, the breadth of either nasal bone at the bridge and DB, the breadth of the maxillary portion of the nasal wall at the bridge.*

Race	♂		♀	
	SB	*DB*	*SB*	*DB*
Congo	5·44	9·83	5·37	9·21
Gaboon, 1864	5·48	9·82	5·53	9·53
Gaboon, 1880	4·59	10·54	5·12	9·71
Philippines	4·91	8·36	5·14	8·06
Moluccas	5·28	9·12	—	—
Borneo	4·51	9·33	4·54	8·09
Malays	4·69	9·40	—	—
Celebes	5·05	9·34	—	—
Sumatra	5·71	8·94	—	—
Javanese	5·33	9·23	5·11	7·64
Nubians	6·64	10·22	6·60	8·60
Ainos	5·80	8·96	—	—
Hindoos	5·67	8·73	4·91	8·32
English	6·56	9·56	6·10	8·77
Egyptians	6·97	9·49	6·67	8·39
Veddahs	5·98	9·29	5·19	9·17
Chimpanzees	4·52	6·41	4·24	5·91
Gorillas	4·41	9·97	3·81	9·61
Orang-utans	—	[13·57]	—	[11·02]
Hylobates (♂ + ♀) ...	2·70	4·27	2·70	4·27
Symphalangus (♂ + ♀) ...	3·11	4·86	3·11	4·86

maxillary wall are often, as our contours (pp. 428—9) show, considerably curved, but the chord of these arcs will indicate, at any rate approximately, what is the nature of the interracial correlations. Omitting Hylobates and Symphalangus as unsexed and the Orangs we find:

Interracial correlation of nasal bone and maxillary wall

Males + ·238, Females + ·215.

* These values are really the hypotenuses or chords corresponding to the nasal and maxillary portions of the bridge of the nose, and these portions are often curved.

It appears therefore reasonable to assume that racially, where the nasal portion is large, so also is the maxillary portion of the nose. Notwithstanding this and the positive correlation of the simotic and maxillary nasal angles, as well as of the subtenses, the projections of the nasal and maxillary portions on the base of the nasal bridge are *negatively* correlated. The algebraic explanation of this paradox is given below*, but it seems probable that its physiological explanation lies in the relative constancy of the mesodacryal chord. If the reader will examine Table XIV he will see that the variability of the simotic chord relative to its size is almost twice that of the mesodacryal chord, and although some of this may be due to the relatively greater difficulty of accurate measurement the bulk of it is not. The following results will indicate the relative stability of the mesodacryal chord. They are deduced from Tables VIII and XIII, males.

	Mesodacryal Chord	Simotic Chord
Interracial Mean	21·6	8·47
Mean racial S. D.	2·44	1·97
Interracial S. D.	1·37	1·20
$100 \times \frac{\text{Mean racial S. D.}}{\text{Interracial Mean}}$	11·3	23·3
$100 \times \frac{\text{Interracial S. D.}}{\text{Interracial Mean}}$	6·34	14·13
$100 \times \frac{\text{Racial Range}}{\text{Interracial Mean}}$	23·5	58·9

Whichever method we take to measure the variation we see that the mesodacryal chord is far less variable than the simotic chord. The breadth of the base of the nasal bridge is relatively constant. The nasal bridge has to span the nasal base, and whether we deal with the problem from the interracial or intraracial standpoint we realise that the nasal structure has to be considered as a whole, and that its anatomical units are very far from being necessarily evolutionary units, or in

* The problem is algebraically of the following kind: given two right-angled triangles ABC and $A'B'C'$ with C and C' for right angles, then with the usual notation $c^2=a^2+b^2$, $c'^2=a'^2+b'^2$, is it possible for c and c', a and a' and A and A' to be positively correlated together and yet b and b' to be negatively correlated? Clearly if the means be denoted in the usual manner, we have approximately:

$$\bar{b}\,\delta b=\bar{c}\,\delta c-\bar{a}\,\delta a, \qquad \bar{b}'\,\delta b'=\bar{c}'\,\delta c'-\bar{a}'\,\delta a'.$$

Hence multiplying together, summing for all possible pairs and dividing by their number, we have

$$\bar{b}\bar{b}'\sigma_b\sigma_{b'}r_{bb'}=\bar{c}\bar{c}'\sigma_c\sigma_{c'}r_{cc'}+\bar{a}\bar{a}'\sigma_a\sigma_{a'}r_{aa'}-\bar{c}\bar{a}'\sigma_c\sigma_{a'}r_{ca'}-\bar{c}'\bar{a}\sigma_{c'}\sigma_a r_{c'a}.$$

Hence if $r_{cc'}$ and $r_{aa'}$ are positive as the hypothesis supposes, and at least one or both $r_{ca'}$ and $r_{c'a}$ are positive also, the negative term or terms on the right may exceed the positive and $r_{bb'}$ be *negative*. In the case of the simotic and maxillary nasal triangles both $r_{ca'}$ and $r_{c'a}$ are positive, and the last pair of terms on the right is wholly negative and in excess of the first pair. The above result depends of course on $c^2=a^2+b^2$ and $\bar{c}^2=\bar{a}^2+\bar{b}^2$ being nearly true. These give $\bar{c}^2=84{\cdot}83$ against actual $84{\cdot}64$ and $\bar{c}'^2=29{\cdot}68$ against $29{\cdot}16$. These are close enough to justify the use of the above formula, which on putting in the actual numbers gave $r_{bb'}$ the correlation of the projections negative, as the direct investigation gave it. Thus the origin of the negative value for the projections' correlation lies in the negative terms involving the cross-correlations of nasal bone with maxillary height and simotic subtense with maxillary wall, which are themselves positive.

themselves primarily significant for interracial comparison or evolutionary history. The intimate correlations of anatomical units renders them also very frequently of small importance as hereditary characters, and a complex of anatomical units may be much closer to an evolutionary unit,—that entity which as a whole is the subject of selective action. For respiratory efficiency the mesodacryal arc may be of far more importance than either of its components, the maxillary or nasal bone portions. Thus we think it probable that the value of anatomical units in craniometric measurements is liable to be overrated, and in view of their complex and subtle intercorrelations their identification with *independent* "Mendelian units"—whatever the latter may signify—is unjustifiable.

In the series of cuts on pp. 428—9, we have endeavoured to give "type" contours of the nasal bridge for various races on the basis of the classification adopted in Table XXV. The reader is warned that in any race individuals may be found with many of these types. Our "types" are those of individuals whose simotic and maxillary nasal angles, ϕ' and ϕ, are as near as we could get to the mean values of those angles in the race. Not too much weight must of course be placed on the classification of races thus reached, but the diagrams are not without suggestiveness. We have added the Dog with its *negative* simotic subtense, a condition which is just reached in one or two Gibbons. In the case of the dog, however, the dacryon to dacryon section seems to miss the physiognomic nasal bridge, and we have given also a lower section termed on p. 428 the muzzle section. The short strokes mark for each contour the limits of the nasal bone; the contours are in each case from dacryon to dacryon, and were traced after orientating the skull so that the two dacrya and the summit of the bridge were in one horizontal plane. Obviously larger numbers of many more races would provide a more adequate classification, especially if extended into the animal kingdom generally*.

* The Gibraltar skull is the only "ancient type" of man for which we have been able to obtain the nasal bridge constants. They are:

Mesodacryal Subtense	8·6,		Simotic Subtense	2·8	
,, Chord	22·0?		,, Chord	10·8	
,, Arc	31·0?				

These give

$$\alpha = 39{\cdot}1, \quad \alpha' = 44{\cdot}4, \quad \beta = 40{\cdot}9, \quad S = 25{\cdot}9, \quad \phi = 46^{\circ}{\cdot}0, \quad \phi' = 27^{\circ}{\cdot}5,$$

the nasal bridge is thus on the border of the simotic platygephyreal and simotic mesogephyreal groups. The difficulty, however, of determining the dacrya in the absence of the sutures in the cast used is very

Gibraltar Skull.

considerable. The contour of the nasal bridge is shown above. It will be seen to be in no way markedly differentiated. If we accept it as approximating to that of the original, that original would have stood somewhere between the Negroes and the natives of the Moluccas for both the maxillary and simotic nasal angles, i.e. at the Chimpanzee and Symphalangus end of the scales. But the evidence is too fragile to lay any stress on this point.

(13) *Concluding Remarks.* We are aware how much of the present paper is open to criticism on account of the limited number of the racial series dealt with and the sparseness of the individual crania in those series. Notwithstanding we hope that the reader may find suggestive paths leading off from these preliminary researches. We believe that the time must come when in the larger Universities there will exist established schools of craniometry with adequate anatomical, physical and statistical training, and that such schools will carry on secular work in collecting and measuring. We have indicated in this paper that the study of the personal equation of craniometricians has hardly begun, but we look forward to the day when it will be as customary for one of the workers in an established craniometry laboratory to be adopted as a standard and his personal equation relative to other workers at home and abroad discussed, as it is for one astronomical observer to be tested against a second. The intercomparability of measurements is largely taken on blind trust by craniologists to-day. Only when relative personal equation has been studied will it be possible safely to pool the measurements of small series made by different laboratories.

Again, anatomical and zoological museums and collections are singularly defective at the present time. If it were desirable to make a thorough study of the cranium of any animal other than man—say dog or horse—is there any collection which could place at the disposal of the inquirer a hundred crania of definite sex, fairly uniform age and reasonable limits of race? We sadly fear not, and yet how much could be learnt of evolutionary descent by an exact study of a variety of species based on even a hundred crania from each! Take the plane of the foramen magnum, determined say by a plane through basion and opisthion perpendicular to the sagittal plane, and consider the angle this makes with the horizontal plane of the skull, as determined, say, by the Frankfurt Concordat. This angle —closely allied to Dauberton's angle—is of very great evolutionary importance, but who can say—on the basis of really numerically adequate measurements* and other than from mere impression gained on a few specimens—what its value is in the chief mammals, in the anthropoid apes, in negroes and in the various other races of man? Comparative craniometry is almost at its origins if we refer, not to descriptions of "typical"† crania, but to the measurement of numerically adequate series. Not until investigations, only roughly foreshadowed in such a paper as the present, have been made on a far greater variety of species and on a wide range of cranial characters—and this will have to wait until adequate material accumulates in our museums—would any suggestion of evolutionary descent pass into comparative certainty. When the reader realises that some 25 gorilla skulls of one sex, but of all ages

* We do not wish for a moment to underrate Broca's work in this field; but besides his views as to the horizontal planes, his series are often unsexed, and, especially for the chief mammals, wholly inadequate numerically. Thus he uses two or three apes, dogs, cats, and so forth, where we need 50 to 100 of each breed and sex.

† How few anatomists realise that nobody knows what a "typical" cranium is until a *long* series of the particular race has been measured! We remember seeing in one museum a skull, labelled "typical English," and this at a date when not 50 English crania from one district and period had been measured.

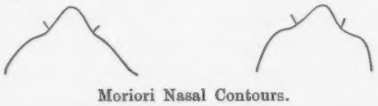
and all districts, are about all that the English worker has to rely upon at present, and that it may be doubted whether he could find the same number of dog skulls of known sex, of *one breed* and of fairly certain age, anywhere in the country, he will, we hope, pardon one source of the inadequacy of the present study.

In choosing the nasal bridge we had in view the importance of the nasal organs as a factor of survival, and we believe we have at least indicated that with caution the parts of the bridge can be measured and comparative results obtained. The measurements lead directly, we think, to the suggestion of a racial scale and throw light on the importance of dealing with groups of correlated characters and not with isolated anatomical units. The classification we have suggested, both in the limits of its categories and its terminology, is of course not put forward as final, but we believe it will be helpful as a step to a good ultimate classification and as enabling meanwhile the characters of the nasal bridge of any other race to be associated with those treated in this paper. The needful measurements are simotic chord and simotic subtense, and again mesodacryal chord and subtense; from the first two the simotic nasal angle can be readily found and from all four the maxillary nasal angle. The two taken in conjunction will enable the recorder to classify the nose by aid of Table XXV.

On the whole we consider that Mérejkowsky broke fruitful ground, especially, if the discussion of the nasal bridge be extended to the mesodacryal chord and subtense, which appear of more evolutionary importance than his simotic chord and subtense; but there will undoubtedly have to be standardisation of individual craniometricians in a far higher degree than even for the macrometric measurements of the skull, if these micrometric measurements are to be dealt with confidently.

Addendum. Since this paper was written, it occurred to us that the Moriori crania from Chatham Island in the Royal College of Surgeons might be worth investigating from the standpoint of the nasal bridge—as they are undoubtedly worth investigating from their general craniometric importance.

The nasal bridges, however, turned out to be of no markedly primitive type, as the accompanying contours will indicate.



Moriori Nasal Contours.

They are mesotic mesogephyreal, and stand between Malay and Aino with:

	♂	♀
ϕ	46·0°	49·0°
ϕ'	40·6°	34·3°

48 crania were taken as male, 15 as female.

There is a somewhat noteworthy difference between male and female, but a still more remarkable feature of the results is that for the *whole* eleven characters discussed the male is more variable and in some cases no less than twice as variable as the female. Such exaggerated differences in variation in the sexes are so unusual, especially in primitive races, that we believe that the noteworthy cranial characters of this race, in which "maleness" seems almost a racial character, may have led to a far too stringent selection of female crania. Thus on the present sexing the female coefficient of variation of the mesodacryal subtense is 8·0, of the mesodacryal index α, 8·0, and of the simotic index 14·4,—all values much below any reached for females of the human races given in Table XIV. We consider it better to postpone publication of the Moriori results, until a fuller study has been made of all the craniological characters of the Royal College series, which we hope may soon be undertaken.

Tables A—D give the measurements made for the apes only. The tape measurements of the mesodacryal arc scarcely ever permitted of the determination to tenths of a millimetre, and this makes the tenths in the mesodacryal chord of small value, when we are determining the arcual index β. In the tables doubt as to a value is only expressed in the columns of the absolute measurements and not repeated in the index columns deduced from these absolute measurements. Of course the index values have no more weight than the data from which they are deduced.

Note. The Editor is responsible for the terminology used in this paper. He fully admits its barbarism. But no English form for the Greek adjective exists, and when a distinguished classical scholar fails to find one, science must take the matter into its own hands, and adjectives in -otic seem the only possibility. *Simotic* has practically Greek sanction; the pathologists have already adopted *stenotic*; thus the step to *mesotic* was not a very great one, and it is shorter than *mesomorphic* or *mesorhinal*,—were indeed compounds in rhinal not already allocated.

TABLE A. *Characters of the*

Museum Number	Sex	Mesodacryal Chord	Mesodacryal Arc	Mesodacryal Subtense	Mesodacryal Indices				Simotic Chord	Simotic Subtense
					α	α′	α − α′	β		
1011. S	♂	19·5	29	9·1	46·7	49·4	− 2·7	48·7	6·0	3·3
7. 1. 8. 2	♂	21·6	30	9·9	45·8	43·1	+ 2·7	38·9	5·8	4·3
7. 1. 8. 1	♂	29·3	34	7·6	25·9	25·9	0	16·1	8·1	1·8
—	♂	33·5 ?	41 ?	7·6 ?	22·7	31·2	− 8·5	22·4	—	—
1011. u	♂	21·1	32	11·4	54·0	51·3	+ 2·7	51·7	5·7	2·7
1011. c	♂	16·2	23	7·5	46·3	45·1	+ 1·2	42·0	—	—
Okwa	♂	25·4	31·5	8·6	33·9	32·4	+ 1·5	24·0	—	—
7. 1. 8. 4	♀	19·1	29·2	9·2	48·2	52·1	− 3·9	52·9	3·6	2·2
7. 1. 8. 5	♀	22·2	31·7	9·6	43·2	45·6	− 2·4	42·8	5·4	3·3
7. 1. 8. 3	♀	25·6 ?	33 ?	9·0	35·2	36·1	− ·9	28·9	4·7	3·8
7. 1. 8. 7	♀	25·0	32	9·2	36·8	35·4	+ 1·4	28·0	5·6	2·6
7. 1. 8. 6	♀	21·8 ?	30·6 ?	10·3	47·2	44·1	+ 3·1	40·4	4·0 ?	1·8 ?
64. 12. 1. 1	♀	17·8 ?	28 ?	10·0	56·2	54·8	+ 1·4	57·3	—	—
1011. d	♀	21·3	32·5	10·2	47·9	51·9	− 4·0	52·6	4·2	2·6
—	♀	21·5 ?	34 ?	10·1 ?	47·0	55·3	− 8·3	58·1	7·5 ?	5·7 ?
1011. b	♀	16·2	23	7·5	46·3	45·1	+ 1·2	42·0	3·0	2·0
22	♂	16·8	27 ?	11·0	65·5	56·9	+ 8·6	60·7	4·1	3·6
20	♂	18·7	23	5·3	28·3	31·6	− 3·3	23·0	—	—
21	♂	25·9	37	11·4	44·0	45·7	− 1·7	42·9	8·8	3·7
28	♂	22·6	30	8·7	38·5	38·8	− ·3	32·7	5·0	2·4
25	♂	22·0	33	8·6	39·1	50·3	−11·2	50·0	3·8	2·7
21. a	♂	25·0	30	7·2	28·8	29·2	− ·4	20·0	8·2	3·6
23	♀	23·8 ?	34 ?	10·5 ?	44·1	45·7	− 1·6	42·9	6·4	2·0
26	♀	24·2	31	8·3	34·2	35·5	− 1·3	28·1	6·0	2·6
27	♀	12·5 ?	19 ?	6·2 ?	49·6	45·7	+ 3·9	52·0	—	—
24	♀	22·0	28	8·4	38·2	34·9	+ 3·3	27·3	9·1	2·2
93	♂	20·3	29	8·4	41·4	45·7	− 4·3	42·9	8·7	3·9
—	♂	26·5	32	8·9	33·6	29·9	+ 3·7	20·8	6·0	3·1
T	♂	23·2	30	9·2	39·7	36·4	+ 3·3	29·3	8·2	3·7
T	♂	21·7	32	10·7	49·3	48·7	+ ·6	47·5	7·0	1·5 ?
—	♀	21·2	34	11·2	52·8	56·7	− 3·9	60·4	5·4	2·7
3	♀	19·0	23	5·4	28·4	30·1	− 1·7	21·1	4·2	1·1
6. 124	♀	11·8	17	6·4	54·2	46·5	+ 7·7	44·1	5·6	3·3
4	♀	19·5	31	11·6	59·5	55·8	+ 3·7	59·0	5·6	3·5
43. 5	♀	24·8 ?	30 ?	8·1	32·7	30·0	+ 2·7	21·0	—	—
"Gerrard"	♀	21·7	26	7·6	35·0	29·1	+ 5·9	19·8	—	—
5 xii. *05*	♀	28·0 ?	29 ?	10·2	36·4	—	—	3·6	—	—
16	♀	16·2 ?	28 ?	9·9	61·1	64·1	− 3·0	72·8	3·2	3·2
2	♀	17·6 ?	25 ?	7·6	43·2	45·2	− 2·0	42·1	—	—
3	♂	25·4	34	9·4	37·0	39·6	− 2·6	33·9	9·2	3·8
1[a]	♂	22·0 ?	30 ?	9·8	44·6	41·4	+ 3·2	36·4	—	—
1161. F	♂	18·2	28	9·6	52·8	52·7	+ ·1	53·9	4·2	3·1
1161. A	♂	24·7	36·5	12·9	52·2	48·9	+ 3·3	47·8	3·2	3·4
423. 5	♂	17·0	23	7·2	42·4	40·6	+ 1·8	35·3	3·0	2·2
7	♂	23·8 ?	33 ?	10·0	42·0	42·9	− ·9	38·7	6·0	2·9
L	♂	30·0	36·5	8·5	28·3	30·6	− 2·3	21·7	8·8	2·9
8	♂	20·9	32·5	11·6	55·5	53·7	+ 1·8	55·5	4·0	4·1
10	♂	19·7	28	9·0	45·7	45·2	+ ·5	42·1	6·5	5·0
1	♂	21·0	30	8·9	42·4	45·7	− 3·3	42·9	8·0	3·5
1	♂	25·0 ?	32·5 ?	8·9	35·6	36·9	− 1·3	30·0	—	—
2052	♂	21·8 ?	28 ?	6·5	29·8	35·8	− 6·0	28·5	8·8	3·0
982	♂	21·0 ?	27 ?	9·7	46·2	35·9	+10·3	28·6	—	—
2051	♀	15·4	23	6·9	44·8	49·9	− 5·1	49·4	6·2	4·3

Nasal Bridge in the Gorilla.

Simotic Index	Locus	Remarks
55·0	Natural History Museum	Sutures very vague
74·1	" " "	From Okuni district. Sutures clear
22·2	" " "	From Okuni district. Sutures vague [specimen mounted in case
—	" " "	Measurements uncertain owing to bad light and position of
47·4	" " "	Very large and heavy skull. Sutures not clear
—	" " "	Permanent teeth not quite erupted. Nasal bones too narrow to
—	" " "	Nasal bones too narrow to measure [measure
47·4	" " "	From Okuni district. Sutures vague
61·1	" " "	From Okuni district. Sutures clear
80·9	" " "	From Okuni district. Sutures vague
46·4	" " "	From Okuni district. Sutures very vague
45·0	" " "	From Okuni district. Sutures vague
—	" " "	In the Du Chaillu collection. Sutures obliterated
61·9	" " "	Sutures clear [specimen mounted in case
76·0	" " "	Measurements uncertain owing to bad light and position of
66·7	" " "	Young. Permanent teeth not quite erupted. Nasal bones
87·8	Royal College of Surgeons	Sutures clear [very narrow
—	" " "	Sutures clear. Split skull and therefore measurements uncertain. Nasal bone abnormal on one side
42·1	" " "	Heavily made skull. Sutures clear. Nasal and maxillary bones large, lacrymal bones very small
48·0	" " "	Young. Permanent teeth erupting
71·1	" " "	Split skull
43·9	" " "	Sutures clear [sutures are vague
31·3	" " "	Difficult to measure as skull is attached to skeleton in case and
43·3	" " "	Sutures vague
—	" " "	Adolescent. Split skull with badly fitting halves. Sutures
24·2	" " "	Perfect sutures [complex
44·8	University College, Zoology Department	Young adult. Sutures clear
51·7	" " " " "	Sutures rather vague
45·1	Professor Thane	Sutures vague
21·4	" "	Sutures very vague
50·0	Professor Pearson, Biometric Laboratory	Sutures vague
26·2	Cambridge Anthropological Laboratory	Sutures clear
58·9	" " " " "	Young adult. Sutures clear
62·5	" " " " "	Sutures clear
—	" " " " "	Sutures obliterated. Skull varnished
—	" " " " "	Sutures obliterated
—	" " " " "	Young. Third molar and canines not yet erupted. Nose apparently damaged and deformed. Omitted from statistical
100·0	" " " " "	Sutures obliterated. A high, narrow nose [reductions
—	" " " " "	Sutures obliterated. Fourth molar appearing on right side
41·3	" " " " "	Sutures clear. Bicuspids out of place on right side
—	" " " " "	Sutures very vague
73·8	Cambridge Zoological Laboratory ...	Sutures clear [bones
106·3	" " " " ...	Sutures clear. Very narrow nasal bones and large maxillary
73·3	Dr W. L. H. Duckworth	Young. Third molars and canines erupting
48·3	" " "	Sutures obliterated
33·0	" " "	Sutures clear but complex. Heavily developed skull
102·5	" " "	Sutures clear, but measurements rather uncertain on account of ossicles in naso-maxillary suture
76·9	" " "	Sutures obliterated. Much developed crest
43·8	" " "	Sutures clear. Heavily developed skull
—	Oxford Museum	Sutures obliterated. Cleft in sagittal cres
34·1	" "	Sutures obliterated
—	" "	Aged. Sutures obliterated
69·4	" "	Nearly adult. Sutures clear. Third molar nearly erupted

TABLE B. *Characters of the*

Museum Number	Sex	Meso-dacryal Chord	Meso-dacryal Arc	Meso-dacryal Subtense	Mesodacryal Indices				Simotic Chord	Simotic Subtense
					α	α'	$\alpha - \alpha'$	β		
7	♂	20·0	27	7·1	35·5	40·4	− 4·9	35·0	6·0	·8
10	♂	14·8	16·8	3·8	25·7	23·5	+ 2·2	13·5	8·6	2·5
11. A	♂	15·2	19	4·8	31·6	33·2	− 1·6	25·0	5·0	1·3
11. 2	♂	15·1	18·5	2·7	17·9	31·2	−13·3	22·5	9·8	1·8
10. A	♂	17·2	21	4·6	26·7	30·9	− 4·2	22·1	—	—
8	♂	16·0	19	3·9	24·4	28·3	− 3·9	18·8	8·2	2·1
9	♂	19·9	23	5·5	27·6	25·5	+ 2·1	15·6	7·7	·6
12	♂	21·1	27	5·5	26·1	35·4	− 9·3	28·0	10·0	1·0
3	♂	19·0	24	5·5	29·0	34·2	− 5·2	26·3	8·0	1·8
1	♂	19·2 ?	22 ?	4·9 ?	25·5	24·6	+ ·9	14·6	—	—
2	♀	19·0 ?	20·2 ?	4·0	21·1	15·7	+ 5·4	6·3	—	—
11	♀	23·0	25	5·4	23·5	18·6	+ 4·9	8·7	8·7	2·4
11. 1	♀	19·0	22 ?	5·0	26·3	25·6	+ ·7	15·8	9·0	1·6
11. B	♀	12·0	15	3·8	31·7	33·2	− 1·5	25·0	7·0	1·0
4	♀	17·0	19·5	2·7	15·9	24·7	− 8·8	14·7	8·7	·6
94	?♂	22·3	26	5·2	23·3	26·4	− 3·1	16·6	—	—
7. 7. 8. 19	♂	25·0 ?	31	6·8	27·2	32·4	− 5·2	24·0	—	—
94. 7. 25. 2	♂	21·0	23·7	6·4	30·5	23·0	+ 7·5	12·9	8·0	3·0
64. 12. 1. 7	?♀	19·0	22	5·4	28·4	25·6	+ 2·8	15·8	9·0	·9
87. 12. 1. 1	♂	14·1	17	4·8	34·0	29·7	+ 4·3	20·6	7·4	1·5
2. e	?♂	20·0	27	7·6	38·0	40·4	− 2·4	35·0	8·2	1·7
82. 9. 18. 1	?♂	22·0	25 ?	3·7 ?	16·8	23·6	− 6·8	13·6	—	—
64. 12. 1. 6	?♂	18·2	22	6·3 ?	34·6	30·0	+ 4·6	20·9	8·4	2·0
Koo Loo *2. 1*	?♂	20·5	26·5 ?	7·8	38·1	36·4	+ 1·7	29·3	—	—
Talbot *33*	?♂	18·2	24 ?	6·1	33·5	38·2	− 4·7	31·9	—	—
90. 6. 8. 1	♂	19·2 ?	24·2 ?	6·5	33·9	33·9	·0	26·0	—	—
65/11 (b)	?♂	16·0	18	3·7	23·1	22·6	+ ·5	12·5	—	—
65/11 (a)	?♀	22·0	28·5	6·2	28·2	36·5	− 8·3	29·5	—	—
1. 8. 9. 84	♀	15·2	21	6·0	39·5	42·6	− 3·1	38·2	—	—
7. 1. 8. 8	?♀	18·0	21·5	5·4	30·0	28·7	+ 1·3	19·4	—	—
1. 8. 9. 10	♂	21·0	25	5·9	28·1	28·5	− ·4	19·1	—	—
94. 7. 25. 3	?♀	20·0	25·5	7·3	36·5	35·1	+ 1·4	27·5	7·0	2·0
95. 4. 11	♀	21·0	26	7·3	34·8	32·3	+ 2·5	23·8	—	—
2. a	♂	19·8	24	6·2	31·3	30·2	+ 1·1	21·2	—	—
83	♀	11·0	13	2·4	21·8	27·7	− 5·9	18·2	8·2	1·8
90. 6. 8. 2	♀	14·3	18	4·5 ?	31·5	33·9	− 2·4	25·9	7·0	1·9
61. 7. 29. 12	♂	23·2	28	4·9	21·1	29·8	− 8·7	20·7	—	—
83. 7. 28. 18	♀	18·8	25·5 ?	5·8	30·9	40·8	− 9·9	35·6	—	—
87. 12. 1. 2	♂	19·0	24·5	7·3	38·4	36·1	+ 2·3	28·9	—	—
A	♀	19·0	23	5·3	27·9	30·1	− 2·2	21·1	8·0	1·0
B	?♂	16·2	20	5·3	32·7	32·0	+ ·7	23·5	12·8	3·0
C	?♀	21·0 ?	24 ?	5·3	25·2	24·3	+ ·9	14·3	—	—
D	♂	8·8	13	3·5	39·8	48·8	− 9·0	47·7	—	—
K	♂	20·0 ?	25 ?	6·0	30·0	33·2	− 3·2	25·0	—	—
5	♀	13·2	19	5·1	38·6	46·4	− 7·8	43·9	—	—
E	♂	19·6 ?	23·5 ?	6·3 ?	32·1	29·2	+ 2·9	19·9	—	—
1163	?♂	22·8 ?	28·5 ?	7·0 ?	30·7	33·2	− 2·5	25·0	—	—
1	♂	19·5	21	3·9	20·0	17·4	+ 2·6	7·7	—	—
2	?♂	13·0	18	4·6	35·4	42·8	− 7·4	38·5	—	—
1	?♂	15·0	18	3·6	24·0	29·2	− 5·2	20·0	—	—
2049[b]	♀	14·8	17·4	4·7	31·8	27·2	+ 4·6	17·6	—	—
979	♂	19·1 ?	21·5 ?	5·2 ?	27·2	22·7	+ 4·5	12·6	—	—

Nasal Bridge in the Chimpanzee.

Simotic Index	Locus	Remarks
13·3	Royal College of Surgeons	Adolescent. Sutures clear
29·1	" " "	Sutures clear. A wide nose with abnormal nasal bones
26·0	" " "	Nearly adult. Sutures clear. Nasal bones narrow
18·4	" " "	Two sutures clear but the third suture quite obliterated
—	" " "	Sutures obliterated
25·6	" " "	Sutures very vague
7·8	" " "	Sutures very vague. Split skull
10·0	" " "	Sutures fairly clear
22·5	" " "	Sutures very vague
—	" " "	Sutures quite obliterated. Measurements uncertain owing to the position of the skull, which is attached to the skeleton in an exhibition case
—	" " "	Sutures obliterated. Measurements uncertain owing to the position of the skull, which is attached to the skeleton
27·6	" " "	Aged [in an exhibition case
17·8	" " "	Sutures very vague
14·3	" " "	Young adult. Sutures clear
6·9	" " "	Two of the sutures clear
—	University College, Zoology Department	Sutures clear
—	Natural History Museum	Sutures obliterated. A large skull with very broad nose
37·5	" " "	Sutures clear
10·9	" " "	Sutures clear
20·3	" " "	Young. Three molars erupting. Sutures clear
20·7	" " "	Sutures fairly clear
—	" " "	Sutures obliterated
23·8	" " "	Sutures obliterated
—	" " "	Sutures obliterated
—	" " "	Sutures rather vague
—	" " "	Sutures obliterated
—	" " "	Young. Third molar erupted
—	" " "	Sutures obliterated
—	" " "	Aged. Sutures obliterated
—	" " "	Aged. Sutures obliterated
—	" " "	Aged. Sutures obliterated
28·6	" " "	Aged. Sutures rather vague
—	" " "	Sutures obliterated
—	" " "	Sutures vague
22·0	" " "	Sutures clear
27·1	" " "	Sutures vague
—	" " "	Sutures obliterated
—	" " "	Sutures obliterated
—	" " "	Sutures obliterated
12·5	Cambridge Anthropological Laboratory	Young. Third molar erupting. Sutures clear
23·4	" " " " "	Young. Third molar erupting. Very broad nasal bones and
—	" " " " "	Sutures obliterated [narrow maxillary
—	" " " " "	Young. Third molar erupting. Sutures obliterated. Omitted from statistical reductions owing to incomplete develop-
—	" " " " "	Aged. Sutures obliterated [ment
—	" " " " "	Young adult. Sutures clear
—	" " " " "	Sutures obliterated
—	Cambridge Zoological Laboratory ...	Sutures obliterated
—	Dr Duckworth	Sutures clear
—	" "	Young. Third molar and canines erupting
—	Oxford Museum	Fronto-maxillary suture obliterated
—	" "	Sutures clear
—	" "	Sutures obliterated

TABLE C. *Characters of the*

Museum Number	Sex	Meso-dacryal Chord	Meso-dacryal Arc	Meso-dacryal Subtense	Mesodacryal Indices			
					α	α′	α − α′	β
39	♂	18·0?	36	11·8?	65·6	79·6	−14·0	100·0
41	♂	16·8	59?	12·6	75·0	160·1	−85·1	251·2
37	♂	15·2	34·2	10·7	70·4	93·4	−23·0	125·0
38	♂	13·8	37?	12·9?	93·5	116·6	−23·1	168·1
38. A	♂	17·5	35	8·6	49·1	79·6	−30·5	100·0
45	♂	11·8	33?	11·4	96·6	122·7	−26·1	179·7
42	♂	16·8	38?	11·0	65·5	94·1	−28·6	126·2
40. A	♀	10·0	25·3	7·7	77·0	108·5	−31·5	153·0
40. B	♀	13·4	35·5	9·1	67·9	114·9	−47·0	164·9
40. E	♀	11·6	23	6·8	58·6	78·7	−20·1	98·3
44	♀	13·8	27·3	9·2	66·7	78·4	−11·7	97·8
44. A	♀	12·7	27	9·7	76·4	86·6	−10·2	112·6
46	♀	12·0	28·2	9·3	77·5	98·9	−21·4	135·0
—	♂	16·6	29	8·5	51·2	65·2	−14·0	74·7
59. 8. 16. 2	♂	11·0	33	12·7	115·5	133·4	−17·9	200·0
1101	♂	12·0	38	14·7	122·5	142·2	−19·7	216·7
92. 11. 5. 14	♂	18·8	31	9·7	51·6	59·4	− 7·8	64·9
55	♂	17·1	26	7·7	45·0	51·6	− 6·6	52·1
1087	♀	11·4	31	10·9	95·6	118·6	−23·0	171·9
1179. a	♂	10·2	29	10·5	102·9	125·2	−22·3	184·3
3. b	♂	13·8	31?	10·0	72·5	93·2	−20·7	124·6
—	?♂	14·0	35?	14·5	103·6	106·9	− 3·3	150·0
3. i	♂	15·2	30·5	11·2	73·7	80·0	− 6·3	100·7
92. 11. 5. 4	♂	17·0	35	11·6	68·2	82·9	−14·7	105·9
3. b^2	?♂	14·0	33	12·4	88·6	99·3	−10·7	135·7
3. m	♀	13·4	24	10·5	78·4	67·8	+10·6	79·1
32	♀	17·7	40	13·1	74·0	94·0	−20·0	126·0
79. 11. 21. 24	♀	13·0?	33·5?	11·1	85·4	111·1	−25·7	157·7
52. 12. 26	♂	16·0?	35?	9·6	60·0	90·0	−30·0	118·8
8. 7. 17. 1	♂	14·8	26	9·5	64·2	65·8	− 1·6	75·7
98. 2. 28. 11	♂	15·0	32	10·7	71·3	87·0	−15·7	113·3
3. j	♂	19·7	34	10·6	53·8	64·0	−10·2	72·6
3. a	♂	18·0	37	13·4	74·4	82·8	− 8·4	105·6
3. d	♂	15·6?	39	11·9	76·3	106·9	−30·6	150·0
3. q^2	♂	12·4	25	9·4	75·8	80·5	− 4·7	101·6
3. c^2	♂	13·8	32?	10·9	79·0	97·2	−18·2	131·9
92. 11. 5. 5	♂	20·8	37	11·0	52·9	67·1	−14·2	77·9
68. 16. 42	♂	16·0	28·5?	10·2	63·8	67·2	− 3·4	78·1
92. 11. 5. 3	♂	20·8	32	8·4	40·4	52·7	−12·3	53·9
85. 20. 7. 1	♂	16·0	29?	9·0	56·3	69·0	−12·7	81·3
85. 2. a 7. 2	♀	10·8	25	9·5	88·0	97·0	− 9·0	131·5
4	♂	14·7	34?	11·8	80·3	96·9	−16·6	131·3
3	?♂	16·0	34	12·4	77·5	86·6	− 9·1	112·5
2	?♂	13·0	32·5?	11·4	87·7	106·9	−19·2	150·0
1	♂	15·7?	33?	12·2	77·7	85·3	− 7·6	110·2
5	?♀	10·5?	26?	9·7	92·4	105·6	−13·2	147·6
1160. A	♂	15·0?	26?	7·1	47·3	64·4	−17·1	73·3
1160. G	♂	13·0	32	11·7	90·0	104·9	−14·9	146·2
1160. D	♂	12·5	33	11·7	93·6	114·4	−20·8	164·0
1163. C	♀	12·0	26	8·4	70·0	88·9	−18·9	116·7
1136	?♀	9·8	34	12·0	122·4	157·9	−35·5	246·9
D. *1*	♂	15·0	28	9·3	62·0	72·1	−10·1	86·7
D. *2*	♂	15·0	32?	10·0	66·7	87·0	−20·3	113·3
2	♂	14·7?	32	10·3	70·1	89·4	−19·3	117·7
A	♂	17·5	43	15·7	89·7	104·6	−14·9	145·7
I^a	♀	11·0	27	8·4	76·4	104·5	−28·1	145·5
2043[a]	♀	9·0	28?	10·1	112·2	139·2	−27·0	211·1
2043	♂	14·7	41?	15·3	104·1	122·3	−18·2	178·9
1	♂	15·7	35·5	11·9	75·8	94·0	−18·2	126·1

Nasal Bridge in the Orang-utan.

Locus	Remarks
Royal College of Surgeons	Split skull with ill-fitting halves
" " "	Sutures very vague
" " "	Sutures clear
" " "	Sutures clear
" " "	Sutures clear
" " "	Sutures clear
" " "	Sutures clear
" " "	Sutures vague. Teeth misplaced
" " "	Sutures clear
" " "	Young. Sutures clear. Third molars erupting
" " "	Adult, but one third molar never erupted. Sutures clear
" " "	Sutures clear
" " "	Sutures clear
University College, Zoology Department	Lacrymo-maxillary suture not very clear
Natural History Museum	Sutures clear [side
" " "	No nasal bones. Maxillary bones meeting with ossicle on right
" " "	Sutures fairly clear. Unusually broad nose for an orang
" " "	Very aged. A large skull with broad nose and much developed crests. Sutures vague
" " "	Fragment only. Sutures clear
" " "	In the Whale Room
" " "	
" " "	In the Whale Room
" " "	Sutures clear
" " "	Sutures clear
" " "	Aged. Sutures rather vague
" " "	Lacrymo-maxillary suture obliterated
" " "	Lacrymo-maxillary suture obliterated
" " "	Sutures clear. No nasal bones
" " "	Aged. Sutures clear [much developed crest
" " "	Aged. Sutures clear. Very long "spindle" nasal bone and
" " "	A large skull with rather vague sutures
" " "	Lacrymo-maxillary suture obliterated
" " "	Sutures clear
" " "	Sutures clear
" " "	Sutures clear. Nasal bones very narrow
" " "	Lacrymo-maxillary suture obliterated
" " "	Sutures clear. Very wide nose [bones extremely narrow
" " "	Broken orbits and therefore measurements uncertain. Nasal
" " "	Sutures clear. Very large skull
" " "	Sutures clear
" " "	Young adult. Sutures clear
Cambridge Anthropological Laboratory	Young adult. Sutures clear
" " " "	Sutures clear
" " " "	Young adult. Sutures clear
" " " "	Lacrymo-maxillary suture absent, other sutures clear
" " " "	Young. Third molar and canine erupting. Split skull and therefore uncertain measurements. Believed to be large species. Omitted from statistical reductions
Cambridge Zoological Laboratory ...	Right lacrymo-maxillary suture obliterated, left placed high on
" " " ...	Sutures clear [side of nose
" " " ...	Young adult. Four upper molars on both sides and four lower
" " " ...	Sutures clear [molars on left side
" " " ...	Young. Third molar and canines erupting. Believed to be large species. Omitted from statistical reductions
Dr Duckworth	Sutures clear
" "	Sutures clear
" "	Sutures clear
" "	No nasal bones. Maxillary bones much developed
" "	Sutures clear [incisors and canines
Oxford Museum	Young adult. Bicuspids on each side misplaced behind lateral
" "	Young adult. Sutures clear
" "	Sutures clear. ?Ossicle at dacryon on left side

TABLE D. *Characters of the Nasal Bridge*

Museum Number	Sex	Meso-dacryal Chord	Meso-dacryal Arc	Meso-dacryal Subtense	Mesodacryal Indices				Simotic Chord	Simotic Subtense
					α	α′	α − α′	β		
6. 10. 4. 1	♂	13·2	20	4·3	32·6	51·2	−18·6	51·5	—	—
38. 3. 13. 7	♂	11·0	16	3·5	31·8	47·4	−15·6	45·5	5·5	·9
38. 3. 13. 5	♂	9·0	10	1·2	13·3	21·2	− 7·9	11·1	4·3	·3
81. 3. 15. 1	♂	11·8	17	3·9	33·1	46·5	−13·4	44·1	6·6	·8
4 b	♀♂	15·0	20	4·3	28·7	39·2	−10·5	33·3	5·4	·2
67. 11. 12. 5	♂	15·8	22	3·9	24·7	43·3	−18·6	39·2	—	—
8. 7. 201	♂	12·5	17·5	3·5	28·0	43·8	−15·8	40·0	—	—
58	♂	16·0 ?	23·8 ?	5·9 ?	36·9	49·5	−12·6	48·8	8·0 ?	·7 ?
59	♂	14·2	20·5	4·5	31·7	46·7	−15·0	44·4	6·2	·8
64	♀	10·0	15	3·3	33·0	50·3	−17·3	50·0	5·6	·5
65	♂	9·8	15	4·1	41·8	52·2	−10·4	53·1	5·5	·3
66	♂	9·9	15	4·3	43·4	51·2	− 7·8	51·5	4·3	·4
70	♂	11·0	16·5 ?	3·6	32·7	50·3	−17·6	50·0	5·8 ?	·3
71	♂	9·8	13·5	2·8	28·6	42·3	−13·7	37·8	6·0	·4
72	♀	9·0	14·2	3·6	40·0	55·1	−15·1	57·8	4·0	·5
(*5.* a) *43. 12. 7. 5*	♂	11·4	16·5	4·2	36·8	46·9	−10·1	44·8	4·0 ?	·5
11. 2. 24. 4	♂	9·9	20	5·7	57·6	80·8	−23·2	102·0	6·0	1·0
8. 11. 1. 1	♂	13·0 ?	22 ?	5·4	41·5	62·0	−20·5	69·2	—	—
90. 1. 28. 1	♂	12·0	15·5	1·7	14·2	36·3	−22·1	29·2	6·0	−·1
1097 a	♂	11·8	17·3	3·9	33·1	48·1	−15·0	46·6	5·3	·1
1097 c	♂	10·4	17·4 ?	4·6 ?	44·2	60·8	−16·6	67·3	—	—
9. 1. 51	♂	10·3 ?	17·3 ?	4·3	41·7	61·3	−19·6	68·0	4·3 ?	·2
1006 a	♂	9·3	17	4·0	43·0	69·9	−26·9	82·8	5·7 ?	·1
'0. 10. 1. 8	♀	11·0 ?	18 ?	4·4	40·0	58·6	−18·6	63·6	—	—
10. 10. 1. 6	♂	10·7	18	3·1	29·0	61·4	−32·4	68·2	5·0 ?	·2 ?
79. 8. 30. 1	♂	11·3	16	3·5	31·0	44·8	−13·8	41·6	6·0	·8
10. 10. 1. 7	♀	11·4	16·6	3·0	26·3	47·5	−21·2	45·6	5·2	·5
54. 10. 5. 1	♂	12·8	20	3·7	28·9	54·2	−25·3	56·3	—	—
1006 d / *48. 1. 27. 46*	♂	11·0 ?	19	4·5	40·9	64·0	−23·1	72·7	—	—
60. 5. 4. 48	♂	9·0 ?	16	3·7	41·1	67·0	−25·9	77·8	—	—
60. 5. 4. 49	♂	9·8	17	4·2	42·9	64·5	−22·6	73·5	—	—
1095 a	♂	9·0	12	2·4	26·7	39·2	−12·5	33·3	5·9	·9
—	♂	11·0	17·5	3·7	33·6	55·9	−22·3	59·1	—	—
1095 c	♂	9·0	15·3	4·5	50·0	62·4	−12·4	70·0	6·6	·7

The symbol ♂ denotes sex unknown.

in the Gibbons, Hylobates and Symphalangus.

Simotic Index	Locus	Remarks
—	Natural History Museum	Hylobates syndactylus. From Pahang. Sutures obliterated
16·4	" " "	From Sumatra. Very young
7·0	" " "	Symphalangus. From Sumatra. Young adult
12·1	" " "	Symphalangus. From Sumatra. Asymmetric lacrymal bones
3·7	" " "	Symphalangus syndactylus. From Sumatra. Old. Sutures vague
—	" " "	Symphalangus syndactylus. Sutures vague. Nasals absent at the bridge
—	" " "	Symphalangus syndactylus. From Pahang. Very old. Sutures quite obliterated
8·8	Royal College of Surgeons	Symphalangus. Old. Sutures obliterated
12·9	" " "	Symphalangus. Old. Sutures rather vague
8·9	" " "	Hylobates sp.
5·5	" " "	Hylobates sp. Young
9·3	" " "	Hylobates lar. Adult
5·2	" " "	Hylobates sp. Old. Sutures vague, nasal sutures obliterated
6·7	" " "	Hylobates sp. Young
12·5	" " "	Hylobates sp. Very young [rated
12·5	Natural History Museum	Hylobates leuciscus from Malacca. Very old. Sutures oblite-
16·7	" " "	Hylobates hainanus from Hainan. Young. Peculiar lacrymal bones [rated
—	" " "	Hylobates gabriella from Annam. Old. Sutures quite oblite-
−1·7	" " "	Hylobates mulleri from N. Borneo. Nasal sutures vague
1·9	" " "	Hylobates agilis
—	" " "	Hylobates agilis from Sumatra. Sutures obliterated
4·7	" " "	Hylobates leuciscus from Java. Sutures obliterated
1·8	" " "	Hylobates hoolock. Young. Apparently no nasals, but process of frontal
—	" " "	Hylobates lar. From Malay Peninsula. Sutures obliterated
4·0	" " "	Hylobates lar. From Malay Peninsula. Sutures obliterated
13·3	" " "	Hylobates leuciscus from Borneo
9·6	" " "	Hylobates lar. From Malay Peninsula
—	" " "	Hylobates lar. From Malacca. Sutures obliterated
—	" " "	Hylobates sp. Ridge on maxilla. Nasal sutures obliterated
—	" " "	Hylobates lar. From Malacca. Sutures obliterated
—	" " "	Hylobates lar. From Malacca. Nasals broken
15·3	" " "	Hylobates lar. Young
—	" " "	Hylobates lar. Sutures obliterated, bisected skull
10·6	" " "	Hylobates sp. Very young

ON THE CALCULATION OF INTRA-CLASS AND INTER-CLASS COEFFICIENTS OF CORRELATION FROM CLASS MOMENTS WHEN THE NUMBER OF POSSIBLE COMBINATIONS IS LARGE.

By J. ARTHUR HARRIS, Ph.D., Carnegie Institution of Washington, U.S.A.

I. Introductory Remarks.

If one designates as classes the groups of measurements or evaluations segregated out of the whole series under consideration, then those correlations which measure the similarity in character of the individuals of the same class may be designated as intra-class coefficients of correlation, while those which measure the resemblance between the individuals of different but (in some manner) related classes may be designated as inter-class coefficients of correlation.

Intra-class and inter-class should not be confused with intra-racial and inter-racial. These latter terms seem to have been first used in a memoir on Naquada Crania by C. D. Fawcett* and discussed for the local races of the lesser celandine† and in greater detail with anthropometric illustrations by Jacob, Lee, and Pearson‡. Examples of the practical use of inter-racial correlation coefficients are also given by Tschepourkowsky§. By intra-racial correlation as the term is used in these discussions, one understands those coefficients expressing the interdependence between the measures on a series of individuals of the same race. Under inter-racial are included the correlations between the types (means, modes) of a series of races.

In intra-class and inter-class correlation, on the other hand, the unit is always the individual (in the statistical sense), not the type of a series of individuals. The purpose of the correlation is to determine the resemblance for any series of characters of the individuals of sub-classes, or of an associated pair of sub-classes,

* *Biometrika*, Vol. I. pp. 460—461, 1902.
† *Biometrika*, Vol. II. pp. 152—153, 1903.
‡ *Biometrika*, Vol. II. pp. 347—356, 1903.
§ *Biometrika*, Vol. IV. pp. 161—168, 286—312, 1905.

as compared with random pairs from the population (or universe) which they constitute. Thus fraternal correlations are intra-class and also intra-racial, as are also homotypic coefficients. In one case, the "class" is fixed by ancestry and family environment, in the other, by ancestry and individual environment. Avuncular correlations—in which all nephews (nieces) of the descendant generation are compared with all the uncles (aunts) of the ascendant generation—are illustrations of inter-class, but also intra-racial, correlation.

The most familiar illustration of intra-class correlations are the fraternal and homotypic; practically the only inter-class relationships hitherto considered are the avuncular and the cousinship in heredity. But these correlations might be powerful research tools in morphology and physiology as well as in heredity and sociology.

The reason for their limited use in the past is in part technical. When the number of observations is as large as is desirable, the formation and verification of the ordinary correlation table (where each individual of the N used is entered only once) is an irksome task, but when each measurement is compared with a number of others, the purely clerical labour involved in tabulation becomes onerous in the extreme. If n be the number of individuals in any class, the number of combinations within the class is $\frac{1}{2}n(n-1)$, while if the tables be rendered symmetrical* as is generally desirable†, the number of combinations for each class is $n(n-1)$, which gives for the m classes constituting the population $S[n(n-1)]$ or, where n is constant, $m[n(n-1)]$ entries in the intra-class correlation surface. With n as low as 20 and m only 250, this gives 95,000 combinations. In inter-class correlation if p be the number in the first and q the number of observations in the second (associated) class, the permutations for a class are pq, and the entries for the population $S(pq)$, or mpq if both p and q are invariable. Obviously, neither m, p, nor q need be large to give very heavy tables.

The labour involved in constructing such tables and making sure that they are free from errors is very great indeed. To meet this difficulty in extreme cases, Pearson‡ has shown how formulae may be deduced for obtaining the coefficient of correlation between any grades of kindred from the means of arrays into which the kindred may be grouped. The method suggested here reduces the work to still simpler terms, obviating entirely the necessity for the

* For discussions of the advantages of the symmetrical table see K. Pearson and others, *Phil. Trans. Roy. Soc. Lond.* A, Vol. CXCVII. pp. 285—379, 1901; R. Pearl, *Biometrika*, Vol. v. pp. 249—251, 1907; K. Pearson and A. Barrington, *Eugenics Laboratory Memoirs*, No. V., 1909; J. Arthur Harris, *Biometrika*, Vol. VII. pp. 214—218, 1909.

† Jennings (*American Naturalist*, Vol. XLV. pp. 123—128, 1911) has suggested a method of calculating the symmetrical table constant without actually rendering the table symmetrical. I believe his method is not serviceable where more than a single pair of characters are involved.

‡ Pearson, K., *Phil. Trans. Roy. Soc. Lond.* A, Vol. CXCII. pp. 271—274, 1899. For other methods of dealing with problems involving many measurements see *Biometrika*, Vol. II. pp. 69—71, 77—78, 1902.

formation of tables, for the calculation of the means of classes, the standard deviation of classes, or the correlations between them, thus reducing the labour involved in the determination of intra-class or inter-class correlations to a small fraction of that hitherto required. While these short methods when properly applied give coefficients agreeing exactly with those deduced from tables, they cannot be recommended without two special warnings. (*a*) In the hands of inexperienced calculators abstract formulae are likely to result in blunders which would not occur, or at least could be easily detected, if the computations were made from tabled data. (*b*) The tables are, in some of the cases at least, desirable for other purposes, *e.g.*, the testing of linearity of regression.

The underlying principle is very simple. The familiar product moment formula for r_{xy} requires merely the first two moments of x and y around the means and the product moment $\Sigma(x'y')$. Of course, the rough moments may be taken around any origin whatever and referred to the mean by a proper formula. In many cases, there are material advantages* in taking 0 as the arbitrary origin. $\Sigma(x')$, $\Sigma(y')$ are then merely summations of the values of the individual variates; $\Sigma(x'^2)$, $\Sigma(y'^2)$ are summations of their squares; $\Sigma(x')/N$ is the mean, m and $\sigma_x = \sqrt{\Sigma(x'^2)/N - m_x^2}$. Then

$$r_{xy} = \frac{\Sigma(x'y')/N - m_x m_y}{\sigma_x \sigma_y} \quad \text{.....(i).}$$

Now the calculation of the rough moments and the product moments about 0 as origin for individual classes is a very easy task. Indeed, with the aid of a proper machine they may be rapidly obtained without seriating the measurements at all†. Since these rough moments for classes are taken about 0, they can be summed, weighted and summed, or subtracted in any way we please to obtain the rough moments for a correlation surface for the whole population. All of this is rapid machine work requiring but a moiety of time needed in the formation of tables of thousands of entries. Formula (i) is so well known that I shall do nothing further in the way of proof of the validity of the formulae suggested here than to show that the data from the first two moments and the numbers of individuals in the classes can be thrown into an equivalent form.

A word may be said concerning the illustrations given. All are, I believe, of intrinsic biological interest, but they have been chosen primarily for their convenient shortness, which facilitates not only the publication of the raw data, but the checking through of the arithmetical work by the reader. Thus they do not always represent the biologically best series which might have been selected.

* Harris, J. Arthur, "The Arithmetic of the Product Moment of Calculating the Coefficient of Correlation," *American Naturalist*, Vol. XLIV. pp. 693—699, 1910.

† After a little practice with the machine, one can sum the squares almost as readily as the first powers entered on the record sheets, providing the grades are not too high.

II. STATEMENT AND ILLUSTRATION OF PROBLEMS.

Problem I. To form Direct or Cross Intra-class or Inter-class Correlation or Contingency Tables when the Number of Possible Combinations is Large.

A method for the rapid formation of the complete direct intra-class table has been described and illustrated elsewhere *. The method of dealing with both direct and cross intra-class correlations by means of condensed tables has also been indicated†. Both direct and cross inter-class correlation tables (full or condensed) are formed by the same method, but more simply since the entries are $S(pq)$, not $S[n(n-1)]$, and the tables as first formed can be used without reduction. The method of dealing with fractional inter-class correlation tables will be illustrated as a check under Problem V.

Problem II. To Determine the Correlation between a Character and an Array of Associated Characters.

This serves chiefly as a simple introduction to the more complex cases to be described presently. One wishes often to correlate between a first measure and an array of associated measures‡. Tables may be difficult to form or cumbersome, while moments of the arrays of measurements around 0 as origin, $\Sigma(y')$ and $\Sigma(y'^2)$, may be wanted for other purposes, or, if not, are at least quickly calculated. Then, by the use of a machine for simultaneous multiplication and addition, we get for the rough moment coefficients

$$S(nx')/S(n) = \nu_x' = m_x, \quad S(nx'^2)/S(n) = \nu_x'' \quad \text{.....(ii)},$$

$$S(y')/S(n) = \nu_y' = m_y, \quad S\Sigma(y'^2)/S(n) = \nu_y'' \quad \text{.....(iii)},$$

and for the rough product moment coefficients

$$S\{x'[\Sigma(y')]\}/S(n) \quad \text{.....(iv)},$$

where n is the number of y measurements associated with any x, $N = S(n)$ is the number of measurements in all arrays or classes, Σ denotes a summation within the class, and S a summation of classes for the whole population. From this point the work is straightforward by (i), *i.e.*

$$r = \frac{S\{x'[\Sigma(y')]\}N - m_x m_y}{\sigma_x \sigma_y}.$$

The particular advantages of this method of calculating correlation are seen in cases where: (*a*) the class moments have already been calculated for other

* Harris, J. Arthur, "On the Formation of Correlation and Contingency Tables when the Number of Combinations is large," *American Naturalist*, Vol. XLV. pp. 566—571, 1911.

† Harris, J. Arthur, "The Formation of Condensed Correlation Tables when the Number of Combinations is large," *American Naturalist*, Vol. XLVI. pp. 477—486, 1912.

‡ A single parent may produce a score or a hundred offspring. Or, one may desire to know the relationship between the weight of the seed planted and the weight of the seeds produced, or between the number of pods per plant and the number of ovules and seeds produced per pod.

purposes, (*b*) it is desirable to calculate several constants from the same material with modified grouping or weighting of some of the classes, (*c*) it is desired to obtain the correlation without seriating the measures for the classes at all*.

Problem III. To Determine Direct and Cross Intra-class Coefficients of Correlation from the First Two Moments of the Individual Classes.

Let x be the measure of a first and y the measure of a second character of an individual of one of the several classes forming the population N. Then if correlations for the population be determined, r_{xy}, where x and y are measures upon the same individual, may be called an organic correlation, while $r_{x_1x_2}$, $r_{y_1y_2}$ may be designated as direct and $r_{x_1y_2}$ as a cross intra-class correlation, where the subscripts 1 and 2 indicate that the measures are taken on a "first" and a "second" individual of the class respectively.

A. *Direct Intra-class Relationships.*

Let n be the number of individual measurements, *e.g.* of siblings or homotypes, in one of m classes. Let Σ indicate a summation within any class and S a summation of classes. For an individual class the rough moment coefficients around 0 as origin are $\Sigma(x')/n$ and $\Sigma(x'^2)/n$, while the possible combinations of individuals are $n(n-1)$. Since the table is symmetrical $m_1 = m_2$, $\sigma_1 = \sigma_2$, and the mean product moment for any class is

$$\{[\Sigma(x')]^2 - \Sigma(x'^2)\}/n(n-1) \quad \text{.....(v),}$$

or for the whole population of m classes

$$S\{[\Sigma(x')]^2 - \Sigma(x'^2)\}/S[n(n-1)] \quad \text{.....(vi),}$$

or when n is constant from class to class

$$S\{[\Sigma(x')]^2 - \Sigma(x'^2)\}/m[n(n-1)] \quad \text{.....(vii).}$$

To complete the calculation of r only the first and second moments for the population are necessary. Two cases are possible: (*a*) the n's are identical for all classes, and (*b*) n differs from class to class. In case (*a*) the moment coefficients for the whole weighted population of $S[n(n-1)] = m[n(n-1)]$ individuals are unchanged by weighting, and are given by

$$S[\Sigma(x')]/N, \quad S[\Sigma(x'^2)]/N \quad \text{.....(viii).}$$

For case (*b*) the arithmetical routine is a little longer, the classes being weighted differently, but always in a $(n-1)$-fold manner. Thus the moment coefficients are

$$S[(n-1)\Sigma(x')]/S[n(n-1)], \quad S[(n-1)\Sigma(x'^2)]/S[n(n-1)] \text{.....(ix).}$$

From this point the calculation of r is straightforward by (i). For clearness both case (*a*) and (*b*) will be illustrated.

* In this case the data for the means and standard deviations are obtained by summing first and second powers of the numbers from the record sheets without classification.

Illustration (III—Aa) 1. *Symmetry in the Ovary of Hibiscus.*

The morphologist interested in the degree of perfection of morphogenetic processes may desire to measure the degree of precision with which the different "*Anlagen*" which go to make up a composite organ, say for example a quinquelocular fruit, are differentiated off from the common primordium and carried through embryogenesis. One convenient measure is furnished by the intra-ovarial coefficient of correlation.

Take as an illustration a series of 1000 five-celled fruits of *Hibiscus Syriacus* from the Missouri Botanical Garden in the fall of 1905. Table I gives the symmetrical intra-ovarial correlation surface for number of ovules per locule.

Since all fruits have the same number of locules, the constants are not changed by weighting, hence, from *Biometrika* (Vol. VIII., pp. 61—62; M.B.G., 1905) we take $\bar{o} = 6{\cdot}4648$, $\sigma_0 = {\cdot}892166$. From Table I,

$$S(o_1'o_2')/N = 841990/20000 = 42{\cdot}0995,$$

$$r = \{S(o_1'o_2')/N - \bar{o}^2\}/\sigma_0^2 = \{42{\cdot}0995 - (6{\cdot}4648)^2\}/({\cdot}892166)^2 = {\cdot}3843.$$

TABLE I. *Symmetry in the Ovary of Hibiscus.*

Ovules of Second Locule.

Ovules of First Locule.	2	3	4	5	6	7	8	Totals
2	—	—	1	2	6	2	1	12
3	—	—	—	1	7	4	8	20
4	1	—	12	28	132	56	23	252
5	2	1	28	220	899	255	55	1460
6	6	7	132	899	6384	1871	605	9904
7	2	4	56	255	1871	2014	1134	5336
8	1	8	23	55	605	1134	1190	3016
Totals	12	20	252	1460	9904	5336	3016	20000

But in *Biometrika* (*loc. cit.* Table VI) we have seriations of total ovules per fruit, $= \Sigma(o')$ for locules. From this and the distribution for individual locules we have for the product moments, by (vii),

$$S[\Sigma(o')]^2 = 1054938, \quad S(o'^2) = 212948, \quad m[n(n-1)] = 20000,$$

whence

$$r = \frac{\{S[\Sigma(o')]^2 - S(o'^2)\}/[mn(n-1)] - \bar{o}^2}{\sigma_0^2} = \{42{\cdot}0995 - (6{\cdot}4648)^2\}/({\cdot}892166)^2 = {\cdot}3843,$$

avoiding all the labour of forming a correlation surface of 20000 entries, but giving no information at all as to the nature of the regression curve.

Illustration (III—Aa) 2. *Intra-ovarial Correlation for Seed Production.*

Next consider a physiological problem from the same data. Table II gives the intra-ovarial (or inter-locular) correlation surface for seeds per locule.

$$\bar{s} = 3{\cdot}9056, \quad \sigma_s = 1{\cdot}756442, \quad S(s_1's_2') = 339360,$$

whence $$r = \{S(s_1's_2')/20000 - (3{\cdot}9056)^2\}/(1{\cdot}756442)^2 = {\cdot}5557.$$

TABLE II.

Intra-Ovarial Correlation for Seeds per Locule.

Seeds of Second Locule.

Seeds of First Locule.	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	Totals
0	70	123	126	54	31	12	4	—	—	420
1	123	334	414	311	150	72	47	8	1	1460
2	126	414	714	642	447	204	102	23	4	2676
3	54	311	642	1002	854	523	237	47	14	3684
4	31	150	447	854	1036	868	522	102	26	4036
5	12	72	204	523	868	1010	752	179	52	3672
6	4	47	102	237	522	752	916	252	84	2916
7	—	8	23	47	102	179	252	150	79	840
8	—	1	4	14	26	52	84	79	36	296
Totals	420	1460	2676	3684	4036	3672	2916	840	296	20000

But the same result can be obtained from the constants for seeds per locule and the seriation of total seeds per fruit (*Biometrika*, Vol. VIII., pp. 60—62) in precisely the same way as in the preceding illustration *without the excessive labour of tabling* 20000 *combinations.*

Suppose, now, we had been given the physical constants only—not the distributions—for seeds (or ovules) per locule and total seeds (or ovules) per fruit. The correlation is still easily deduced, for the sum of the squares of total seeds, $= S[\Sigma(s')]^2$ for locules, is given by substituting from *Biometrika*, Vol. VIII., Table XII,

$$S[\Sigma(s')]^2/N = \Sigma(s_t'^2)/N = \sigma_{s_t}^2 + \bar{s}_t^2 = (7{\cdot}0506)^2 + (5 \times 3{\cdot}9056)^2 = 431{\cdot}05374436,$$

where the subscript t indicates total seeds per fruit. Since $N = 1000$ for fruits,

$$S[\Sigma(s')]^2 = 431053{\cdot}74.$$

In the same manner we get for the individual locules

$$\Sigma(s'^2)/N = \sigma_s^2 + \bar{s}^2 = 18{\cdot}338652,$$

or since N for locules $= 5000$, $\Sigma(s'^2) = 91693{\cdot}26$. Hence, by (vii),

$$r = \{(431053{\cdot}74 - 91693{\cdot}26)/20000 - (3{\cdot}9056)^2\}/(1{\cdot}7564)^2$$
$$= 1{\cdot}71431264/3{\cdot}084941 = {\cdot}5557.$$

The extent of agreement with other methods depends merely upon the number of decimal places retained in the constants.

The importance of intra-class correlation coefficients in physiological work is emphasized by a comparison of this with the preceding, III (Aa) 1, result:

For ovules per locule, $r = {\cdot}3843 \pm {\cdot}0081$.
For seeds per locule, $r = {\cdot}5557 \pm {\cdot}0066$.
Excess for seeds, $= {\cdot}1714 \pm {\cdot}0104$.

The probable errors were calculated on the basis of the actual number of locules, $n = 5000$.

Apparently differences (*a*) in the vigour of the ovules, or (*b*) in the chances of fertilization, or (*c*) in the supply of seed forming substances, from fruit to fruit tend to render the locules more alike in the number of seeds they produce than they are initially in number of ovules*. The discussion of these points must, of course, be reserved until all the data can be set forth.

Illustration (III—Aa) 3. Intra-ovarial Correlation for Seed Weight.

Case (Aa) may be further illustrated by a series of seed weights to be discussed in a forthcoming paper on *Crinum*. Ten seeds from each of 200 fruits taken from a fine row of plants in the Missouri Botanical Garden in the spring of 1906 were weighed. From Illustration 2 it appeared that in *Hibiscus* the locules of the same fruit have a tendency to produce similar numbers of seeds. Here the problem is to determine to what extent the seeds from the same fruit are alike in weight. The seeds range from 1—18 half-gram units†. This would give a symmetrical intra-fruit correlation table of $18^2 = 324$ compartments and $200 \times 10 \times 9 = 18{,}000$ entries. The work is very rapidly carried out by my formulae. The total weight in units for each of the 200 fruits is obtained by simple addition. These, shown in Table III, are of course the class $\Sigma(x')$'s around

TABLE III.

Total weight of seeds (in half-gram units) in Individual Fruits of Crinum.

10	14	19	21	24	27	29	31	33	36	39	41	43	45	49	54	61	70	85	96
10	14	20	21	24	27	29	31	34	36	39	41	43	46	49	55	62	71	86	97
10	15	20	21	24	27	29	32	34	36	39	42	43	46	50	55	62	72	87	100
11	15	20	21	24	28	29	32	34	36	40	42	44	46	50	57	62	73	89	103
12	16	20	22	24	28	30	32	34	37	40	42	44	47	50	58	63	75	89	107
12	17	20	22	25	28	30	32	34	37	40	42	44	47	51	58	64	76	90	115
12	17	20	22	25	28	30	32	35	38	41	42	44	47	52	59	64	78	91	122
13	17	21	23	25	28	30	32	35	38	41	42	45	47	52	59	64	80	93	124
13	18	21	23	25	28	30	32	35	39	41	42	45	48	53	60	66	81	94	125
14	19	21	23	26	29	31	33	35	39	41	43	45	48	53	61	69	84	95	126

0 as origin. The 2000 seeds weighed are distributed as follows:

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
219	396	352	290	212	147	106	76	55	39	27	26	29	13	5	6	1	1

* This is also the conclusion reached for *Sanguinaria*. See Harris, *Biometrika*, Vol. VII. pp. 327—328, 1910.

† Class 1 = 0·0—0·5 gr., class 2 = 0·6—1·0 gr., etc. For details see final paper, *Annual Report Missouri Botanical Garden*, Vol. XXIII. 1912.

With Sheppard's correction this gives* in units of weighing

$$\Sigma(x') = 8778\dagger, \quad \Sigma(x'^2) = 56350,$$
$$\Sigma(x')/N = 4{\cdot}389, \quad \sigma^2 = 8{\cdot}828346.$$

From Table III $$S[\Sigma(x')]^2 = 510496,$$

and we have $$r = \frac{(510496 - 56350)/18000 - (4{\cdot}389)^2}{8{\cdot}828346} = {\cdot}6759,$$

agreeing exactly with the result from the conventional symmetrical table which will be published and discussed elsewhere.

Illustration (III—Ab) 4. Fraternal Correlation when the Number of Combinations is large.

As material for an illustration of the calculation of fraternal (or rather sororal) correlation when the numbers are large, Dr Lutz kindly gave me the measurements of wing lengths in units of $\frac{1}{33}$rd mm. for the females in fifteen families of the Pomace Fly, *Drosophila ampelophila*‡. Table IV shows the distributions of wing length, the class centres only being indicated. Using the method of a former note§, I formed the symmetrical intra-family correlation surface shown in Table V. From this I deduced for the weighted population

$$\bar{l} = 66{\cdot}200653, \quad \sigma_l = 7{\cdot}107332,$$

and for the first rough moments about 0 as origin of the individual arrays the numbers given in the last column of the table. Multiplying up by the grade of the array and summing simultaneously on the machine‖, I got

$$\Sigma(l_1 l_2) = 123391132,$$

whence $$r = [\Sigma(l_1' l_2')/N - \bar{l}^2]/\sigma_l^2 = {\cdot}15883.$$

But, entirely without the labour of forming a heavy table, I find, from the first and second class (family) moments of Table IV,

$$Sn(n-1) = 28148,$$
$$S[(n-1)\Sigma(l')] = 1863416,$$
$$S[(n-1)\Sigma(l'^2)] = 123559412,$$
$$S[\Sigma(l')]^2 = 126124937,$$
$$S\Sigma(l'^2) = 2733805.$$

* Of course, where all the classes comprise the same number of individuals the weighting is uniform and the weighted population constants the same as are those calculated from the unweighted distributions.

† Table III may be conveniently verified by the agreement of its summation with this number.

‡ See *Publications Carnegie Institution of Washington*, 143, pp. 38—40, for some details.

§ *American Naturalist*, Vol. XLV. pp. 566—571, 1911.

‖ *American Naturalist*, Vol. XLIV. pp. 693—699, 1910.

TABLE IV.

Wing Length in Families of Drosophila.

Family	*57*	*59*	*61*	*63*	*65*	*67*	*69*	*71*	*73*	Totals	$\Sigma(l')$	$\Sigma(l'^2)$
31	1	—	1	2	8	12	6	1	—	31	2053	136183
32	—	—	—	—	—	1	9	2	—	12	830	57420
37	1	1	—	3	5	15	9	4	4	42	2832	191426
39	—	1	2	5	10	12	12	7	1	50	3348	224634
57	—	—	—	4	6	18	9	—	—	37	2469	164877
58	—	—	—	1	16	16	11	4	—	48	3218	215928
523	—	—	1	3	7	15	19	8	1	54	3662	248654
575	—	—	3	5	4	3	3	—	—	18	1166	75658
576	—	—	6	12	16	7	8	5	—	54	3538	232270
582	—	—	2	10	12	21	6	2	—	53	3495	230749
587	—	—	—	—	—	2	12	4	—	18	1246	86274
588	—	—	—	4	17	20	12	—	—	53	3525	234613
1177	2	1	5	7	14	14	3	—	—	46	2974	192646
1193	—	—	2	12	18	16	5	—	—	53	3465	226749
1226	—	—	4	18	21	8	1	—	—	52	3348	215724
Totals	4	3	26	86	154	180	125	37	6	621	41169	2733805

TABLE V.

Sororal Correlation for Wing Length in the Vinegar Fly.

Wing of Second Sister.

Wing of First Sister.	*57*	*59*	*61*	*63*	*65*	*67*	*69*	*71*	*73*	Totals	$\Sigma(l_x')$
57	2	3	11	19	41	55	21	5	4	161	10605
59	3	—	7	15	29	41	24	11	5	135	8977
61	11	7	74	253	357	278	147	57	3	1187	77733
63	19	15	253	780	1234	1085	521	157	20	4084	268002
65	41	29	357	1234	2042	2128	1145	322	37	7335	483441
67	55	41	278	1085	2128	2558	1568	427	87	8227	545433
69	21	24	147	521	1145	1568	1212	440	67	5145	343643
71	5	11	57	157	322	427	440	158	31	1608	107682
73	4	5	3	20	37	87	67	31	12	266	17900
Totals	161	135	1187	4084	7335	8227	5145	1608	266	28148	1863416

Whence, writing the formula for r without reduction,

$$r_{l_1 l_2} = \frac{\dfrac{S[\Sigma(l')]^2 - S\Sigma(l'^2)}{S[n(n-1)]} - \left(\dfrac{S[(n-1)\Sigma(l')]}{S[n(n-1)]}\right)^2}{\dfrac{S[(n-1)\Sigma(l'^2)]}{S[n(n-1)]} - \left(\dfrac{S[(n-1)\Sigma(l')]}{S[n(n-1)]}\right)^2} = \cdot 15883,$$

agreeing exactly with the value deduced from the table.

While the case is given as an illustration of method only, chosen primarily because of the small number of families, it is of rather unusual biological interest. These families were from inbred stock (sister by brother) derived originally from a single pair, thus representing as nearly as possible among unisexual organisms a "pure line." Yet we find a sensible sororal correlation*. I hope Dr Lutz will find time to collect really adequate data on this interesting problem.

I illustrate on this data one of the most convenient features of the methods here described. If, for any reason, one wishes to compare the values of correlations determined with and without the inclusion of certain classes, the various determinations can be quickly made by the simple addition or subtraction of the summations of weighted products. For example, suppose one wishes to test the effect of omitting families 32, 575 and 587. $S[n(n-1)]$ will be reduced by

$$12 \times 11 + 2 \times 18 \times 17 = 744;$$

the first weighted population summation by

$$11 \times 830 + 17 \times 1166 + 17 \times 1246 = 50134;$$

the second by

$$11 \times 57420 + 17 \times 75658 + 17 \times 86274 = 3384464,$$

and the product summation by

$$(830^2 - 57420) + (1166^2 - 75658) + (1246^2 - 86274) = 3381620.$$

Deducting these from the comparable values given above for the population and calculating physical constants on the basis of the new weighted population N, we find $r = \cdot 1419$.

Illustration (III—Ab) 5. Direct Homotypic Correlation.

The records of the number of ovules per pod in twelve individual trees of black locust, *Robinia Pseud-acacia*†, may illustrate the calculation of homotypic correlations. The series is selected because of the wide variation in n. Naturally the smallness of the number of classes which renders the material convenient as an illustration of method, makes it of little value biologically. The seriations of numbers of ovules per pod and of numbers of seeds per pod appear in Tables VI and VII. The essentials for the calculation of r appear in Table VIII.

* This may not of course be due to heredity. The environment of the unlaid eggs or differences in the experimental conditions during the larval period may be its source. But Dr Lutz considers sensible environmental heterogeneity out of the question.

† The correlation between the number of ovules and number of seeds developing per pod has been discussed for the combined pods of this series in *Biometrika*, Vol. VI. pp. 441—442, 1909.

TABLE VI.

Ovules per Pod in Robinia.

Tree	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Totals
1	1	3	12	24	21	28	20	6	7	—	—	—	—	—	122
2	—	—	3	4	6	10	11	11	6	6	4	1	2	—	64
3	1	2	3	13	35	25	20	11	1	—	—	—	—	—	111
4	—	3	5	16	31	25	14	6	2	—	—	—	—	—	102
5	—	—	3	13	25	26	31	15	5	1	2	1	—	—	122
6	—	2	3	14	32	31	25	10	1	2	—	—	—	—	120
7	—	—	—	6	10	15	35	25	16	9	1	3	—	—	120
8	—	—	—	—	2	5	22	28	35	31	25	6	4	1	159
9	—	—	—	2	11	29	28	32	14	9	2	—	1	—	128
10	—	—	1	3	5	22	15	20	5	4	2	1	—	—	78
11	—	1	—	8	19	17	20	26	7	3	2	—	2	—	105
12	—	—	—	—	2	12	17	25	36	34	33	20	11	6	196
Totals	2	11	30	103	199	245	258	215	135	99	71	32	20	7	1427

TABLE VII.

Seeds per Pod in Robinia.

Tree	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Totals
1	—	—	5	16	23	27	17	16	8	3	3	—	4	—	—	—	—	—	122
2	—	1	4	4	7	6	8	6	5	6	3	2	4	4	2	1	1	—	64
3	2	13	28	23	11	20	9	3	2	—	—	—	—	—	—	—	—	—	111
4	4	13	19	20	11	11	12	3	5	2	1	1	—	—	—	—	—	—	102
5	—	5	18	10	20	21	21	7	7	4	6	2	—	—	—	1	—	—	122
6	13	33	19	21	15	6	8	1	1	2	1	—	—	—	—	—	—	—	120
7	3	11	20	24	21	11	14	6	7	2	—	1	—	—	—	—	—	—	120
8	—	—	—	6	23	14	21	14	25	20	18	9	5	2	2	—	—	—	159
9	3	15	17	15	13	22	13	9	2	10	3	2	3	1	—	—	—	—	128
10	3	9	15	14	11	8	9	3	3	—	—	1	1	—	1	—	—	—	78
11	—	—	1	3	6	9	12	22	20	17	11	3	1	—	—	—	—	—	105
12	1	—	6	5	7	7	11	8	12	22	23	23	20	16	17	10	6	2	196
Totals	29	100	152	161	168	162	155	98	97	88	69	44	38	23	22	12	7	2	1427

Feeding the entries in Table VIII into the calculating machine and copying off the results I find, for population constants weighted in $(n-1)$-fold manner:

$$S[n(n-1)] = 181152,$$

$$S[(n-1)\Sigma(o')] = 2259669, \qquad \bar{o} = 12{\cdot}473884,$$

$$S[(n-1)\Sigma(o'^2)] = 29203787, \qquad \sigma_o^2 = 5{\cdot}613725,$$

$$S[\Sigma(s')]^2 = 13114598, \qquad S[\Sigma(s'^2)] = 101750,$$

$$S[\Sigma(o')]^2 = 28866082, \qquad S[\Sigma(o'^2)] = 219072,$$

$$S[(n-1)\Sigma(s')] = 1468970, \qquad s = 8{\cdot}109047,$$

$$S[(n-1)\Sigma(s'^2)] = 14364330, \qquad \sigma_s^2 = 13{\cdot}537706,$$

where o and s indicate ovules per pod and seeds per pod.

These give:

$$r_{oo_2} = \frac{\{S[\Sigma(o')]^2 - S[\Sigma(o'^2)]\}/S[n(n-1)] - \bar{o}^2}{\sigma_o^2} = \cdot 452,$$

$$r_{s_1 s_2} = \frac{\{S[\Sigma(s')]^2 - S[\Sigma(s'^2)]\}/S[n(n-1)] - \bar{s}^2}{\sigma_s^2} = \cdot 449.$$

The number of individuals is too small to attach much importance to the result but the agreement with other series of Leguminosae is good*, although the correlation for seeds maturing is frequently considerably smaller than that for ovules formed.

TABLE VIII.

Summations for Individuals of Robinia.

Number of Tree	n	$n(n-1)$	Sum of Ovules, $\Sigma(o')$	Sum of Ovules Squared, $\Sigma(o'^2)$	Sum of Seed, $\Sigma(s')$	Sum of Seeds Squared, $\Sigma(s'^2)$
1	122	14762	1273	13649	912	7394
2	64	4032	796	10256	602	6522
3	111	12210	1183	12839	595	3543
4	102	10302	1064	11310	586	3938
5	122	14762	1378	15896	864	6918
6	120	14280	1299	14311	555	3091
7	120	14280	1490	18850	713	4819
8	159	25122	2251	32331	1495	15117
9	128	16256	1580	19816	860	6894
10	78	6006	946	11690	457	3211
11	105	10920	1245	15135	984	9642
12	196	38220	2875	42989	2347	30661
Totals	1427	181152	17380	219072	10970	101750

Illustration (III—Ab) 6. Tests of the Existence of Sub-races.

O. H. Latter in testing for differentiation in Cuckoo's eggs† according to their foster parents, determined the probable errors of the difference between the means of the several "gentes" and the means of *Cuculus Canorus* as a species. But one may also test for the differentiation of the foster parent "gentes" from the species as a whole by determining the intra-class correlation for egg dimensions. I am especially willing to do this since Latter tested the significance of his divergences by the formula $\cdot 67449\sqrt{\frac{\sigma^2}{n} + \frac{\Sigma^2}{N}}$, whereas Pearson's formula

$$\cdot 67449\sqrt{\frac{\Sigma^2}{N} + \frac{\sigma^2}{n}\left(1 - \frac{2n}{N}\right) - \frac{n(M-m)^2}{N(N-n)}}$$

would have been more suitable but had not then been published‡.

* Pearson, *Phil. Trans.* A, Vol. CXCVII. pp. 364—379; Harris, *American Naturalist*, Vol. XLV. p. 570.

† *Biometrika*, Vol. I. pp. 164—176, 1901; Vol. IV. pp. 363—373, 1905.

‡ *Ibid.*, Vol. V. pp. 181—183, 1906.

Table III of Latter's second memoir furnishes the data. Grouping in units of ·5 mm. we have the results given in Tables IX and X*.

TABLE IX.

Length of Cuckoo's Eggs.

Foster Parent	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*53*	Totals	$\Sigma(l)$	$\Sigma(l^2)$
Robin	—	—	1	1	8	3	9	13	20	6	11	2	2	1	1	78	3559	162819
Garden-Warbler...	—	—	2	4	15	15	19	25	10	—	1	—	—	—	—	91	3988	174992
Meadow-Pipit ...	—	1	1	2	4	10	27	19	8	7	5	2	—	—	—	86	3837	171489
Wren	—	—	7	5	14	8	9	6	3	2	—	—	—	—	—	54	2315	99433
Redstart	—	—	1	—	5	6	21	8	11	6	5	1	—	—	—	64	2869	128821
Sedge-Warbler ...	—	—	2	—	4	11	15	5	6	3	1	1	—	—	—	48	2120	93788
Barred-Warbler ...	—	—	1	4	4	4	11	7	3	—	1	—	—	—	—	35	1529	66899
Whitethroat ...	1	—	—	3	7	6	8	8	2	—	2	—	—	—	—	37	1613	70457
Marsh-Warbler ...	—	—	1	—	3	4	14	6	7	1	1	—	—	—	—	37	1641	72867
Red-backed Shrike	—	—	2	9	20	24	90	67	60	23	9	3	—	—	—	307	13716	613606
White-Wagtail ...	—	—	—	2	10	7	29	33	23	6	4	1	—	—	—	115	5145	230453
Pied-Wagtail ...	—	—	2	1	7	9	20	13	22	5	5	—	1	—	—	85	3804	170532
Reed-Warbler ...	—	—	2	—	7	9	13	7	13	9	4	2	—	—	—	66	2959	132939
Tree-Pipit ...	—	—	—	—	6	2	11	7	6	7	9	—	—	—	—	48	2174	98648
Hedge-Sparrow ...	—	—	—	—	2	5	14	13	13	3	5	—	3	—	—	58	2629	119357
Yellow-Ammer ...	—	—	1	—	6	3	5	7	5	3	—	—	1	—	—	31	1377	61293
Totals ...	1	1	23	31	122	126	315	244	212	81	63	12	7	1	1	1240	55275	2468393

TABLE X.

Breadth of Cuckoo's Eggs.

Foster Parent	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*38*	Totals	$\Sigma(b)$	$\Sigma(b^2)$
Robin	—	—	1	2	17	17	20	14	6	1	78	2621	88233
Garden-Warbler ...	—	—	—	8	39	20	21	3	—	—	91	2975	97355
Meadow-Pipit ...	—	—	1	4	18	19	36	6	2	—	86	2863	95425
Wren	—	—	3	11	19	7	10	4	—	—	54	1750	56810
Redstart	—	—	2	2	17	19	22	2	—	—	64	2111	69703
Sedge-Warbler ...	—	—	—	8	11	13	12	4	—	—	48	1577	51881
Barred-Warbler ...	—	—	2	5	10	9	8	1	—	—	35	1139	37119
Whitethroat ...	1	—	—	5	13	11	6	1	—	—	37	1201	39041
Marsh-Warbler ...	—	—	—	3	14	11	9	—	—	—	37	1210	39602
Red-backed Shrike	—	1	2	10	80	104	94	14	2	—	307	10149	335833
White-Wagtail ...	—	—	3	5	20	27	32	21	7	—	115	3851	129177
Pied-Wagtail ...	—	—	—	5	27	21	28	4	—	—	85	2804	92590
Reed-Warbler ...	—	—	—	4	19	13	20	9	1	—	66	2192	72898
Tree-Pipit ...	—	—	—	2	9	17	14	3	3	—	48	1600	53398
Hedge-Sparrow ...	—	—	—	1	9	18	20	9	1	—	58	1944	65220
Yellow-Ammer ...	—	—	—	1	12	7	10	1	—	—	31	1021	33657
Totals ...	1	1	14	76	334	333	362	96	22	1	1240	41008	1357942

* Since in the method of computation adopted we deal with the summations of first and second powers of actual measurements, not with their deviations from arbitrary origins chosen to lighten computation, we can save materially in the size of the summed products by reducing to half mm. units instead of mm. units, i.e. 15·0=30, 15·5=31, etc.

Summarizing the results from these tables as under illustration (III—Ab) 5, we have:

$$S[n(n-1)] = 159484,$$

$S[(n-1)\Sigma(l')] = 7120158,$		$\bar{l}$	$= 44{\cdot}644967,$
$S[(n-1)\Sigma(l'^2)] = 318370242,$		σ_l^2	$= 3{\cdot}078842,$
$S[\Sigma(l')]^2 = 320370295,$		$S[\Sigma(l'^2)] = 2468393,$	
$S[(n-1)\Sigma(b')] = 5277568,$		$\bar{b}$	$= 33{\cdot}091520,$
$S[(n-1)\Sigma(b'^2)] = 174844798,$		σ_b^2	$= 1{\cdot}266907,$
$S[\Sigma(b')]^2 = 176007866,$		$S[\Sigma(b'^2)] = 1357942.$	

Whence by (vi, ix) as illustrated in greater detail under (III—Ab) 4—5 above I get:

$$r_{l_1 l_2} = {\cdot}046 \pm {\cdot}019, \qquad r/E_r = 2{\cdot}41,$$
$$r_{b_1 b_2} = {\cdot}036 \pm {\cdot}019, \qquad r/E_r = 1{\cdot}85,$$

where the probable errors are calculated on the basis of the actual number of eggs, or $N = 1240$.

Such a test as the above can never replace the *R.L.D.* (relative local difference) or the *R.R.D.* (relative racial difference) as the case may be, of Tocher and Pearson. But there are cases, as for instance the present and several unpublished series, where, now that a (relatively) rapid method of computation is available, it may be very useful.

Illustration (III—Ab) 7. *Inheritance of Milk Yield in the Male Line.*

The test of the inheritance of a character like "milk yield" through the male must be made either by correlating between the milk yield of a cow and her parental granddam, or by determining the correlation between the daughters of individual bulls.

The methods here described are particularly useful for cases of this kind, for while the number of daughters in a family may not be large, the range of variation in yield is apt to be very great thus rendering the tables cumbersome in size, whether or not heavy in number of entries.

As an illustration I take a series of data from a paper by James Wilson, M.A., B.Sc., "On inheritance of Milk Yield in Cattle*." One of his tables (pp. 103—105), gives the milking record of the daughters of eleven Red Danish bulls. Our problem is to determine the correlation in milk production between the daughters of the same sire, in order to ascertain whether there be an inheritance of milking quality in the male line.

The data are of course very rough since they are apparently for the most part recorded to the nearest fifty gallon point. The yields range from 650 to 1400 gallons. Omitting all records indicated as questionable, I sum the yields and

* Wilson, J., *Scientific Proc. Roy. Dublin Society*, n. s. Vol. XIII. pp. 89—113, 1911.

the squares of yields directly from Professor Wilson's table and enter the totals for each bull in Table XI. This gives

$$r_{y_1y_2} = \cdot 126 \pm \cdot 076.$$

The probable error is based on the actual number of daughters, $n = 76$, not the weighted number,

$$S[n(n-1)] = 538.$$

Whether or not this slight correlation in yield (y) is statistically significant, the case illustrates a very convenient method of dealing with such problems. I hope to discuss the biological sides of the question in more detail elsewhere.

TABLE XI.

Milk Yield in Daughters of Various Bulls.

Sire	Number of Daughters	Total Yield $\Sigma(y')$	$(n-1)\Sigma(y')$	$\Sigma(y^2)$	$(n-1)\Sigma(y^2)$
Maxi	11	8900	89000	7310000	73100000
Stamfadern ...	9	8000	64000	7195000	57560000
Braendekilde Max	4	3800	11400	3625000	10875000
Vigfus	6	5900	29500	6090000	30450000
Osvald Ejersminde	6	5500	27500	5120000	25600000
Gunnar	3	2650	5300	2362500	4725000
Mazeppa II ...	6	6400	32000	6875000	34375000
Tordensjold ...	5	4650	18600	4372500	17490000
Trym I	7	6500	39000	6165000	36990000
Taurus IV ...	13	11350	136200	10022500	120270000
Ambrosius III ...	6	5300	26500	4765000	23825000
	76	68950	479000	63902500	435260000

$S[n(n-1)] = 538$, $S[\text{Total yield}]^2 = 491477500$.

B. *Cross Intra-Class Relationships.*

If x and y be two measures on the same individual, and if correlation be determined between the individuals of the m sub-groups or classes constituting the general population, then as pointed out above, $r_{x_1x_2}$, $r_{y_1y_2}$ are direct intra-class correlations while $r_{x_1y_2}$ is a cross intra-class relationship.

The number of combinations will in both direct and cross intra-class relationships be $S[n(n-1)]$, since in the direct correlations one cannot correlate between a measure and itself and in the cross correlations one must not include the relationship between the x and y of the same individual—the organic correlation, r_{xy}.

The value of this direct organic correlation is given by the moment coefficients

$$S[\Sigma(x')]/S(n), \quad S[\Sigma(x'^2)]/S(n), \quad S[\Sigma(y')]/S(n), \quad S[\Sigma(y'^2)]/S(n), \ldots (x)$$

and by the mean product moment

$$S[\Sigma(x'y')]/S(n), \quad \text{(xi)}$$

taken about 0 as origin. Most simply they can be determined by the formation of an ordinary organic correlation table for the whole population which will then be described by N, $S(x')$, $S(x'^2)$, $S(y')$, $S(y'^2)$ and $S(x'y')$, where S denotes a summation for the individuals of the population. This correlation will generally be wanted for its own sake.

Again two cases are possible (α) all the m classes are equally large, (β) n is variable. The first two moments are given by the same formulae as in the direct intra-class correlation above, (viii)—(ix). The mean product moment around 0 is

$$\{S[\Sigma(x')\Sigma(y')] - S[\Sigma(x'y')]\}/S[n(n-1)], \quad \text{(xii)}$$

or with a denominator of $m[n(n-1)]$ where the m classes are equally large.

Illustration (*III—Bα*) 8. *Cross inter-locular* (*intra-ovarial*) *Correlation in Hibiscus.*

For a purpose quite foreign to my present one, the correlation between total ovules per fruit ($=\Sigma(o')$ for locules) and total seeds per fruit ($=\Sigma(s')$ for locules) has been tabled for the 1905 series of *H. Syriacus*. The Table has 17×36 entries, hence we reduce to the condensed form in Table XII. The organic correlation between the ovules and seeds of the same locule is shown in Table XIII. Taking the product moments of these two tables about 0, and subtracting that for locules from that for fruits to remove the products of the ovules and seeds of the same locule, and to reduce N from $S(n^2) = 25000$ to $S[n(n-1)] = 20000$, I find

$$S[\Sigma(o')\Sigma(s')] = 637491, \quad S(o's') = 128377,$$

and, substituting physical constants from illustrations 1 and 2, I find

$$r_{o_1 s_2} = \frac{S\{[\Sigma(o')\Sigma(s')] - S(o's')\}/20000 - \bar{o}\bar{s}}{\sigma_o \sigma_s} = \frac{25{\cdot}4557 - 6{\cdot}4648 \times 3{\cdot}9056}{{\cdot}892166 \times 1{\cdot}756442} = {\cdot}1320\,.$$

TABLE XII.

Correlation for Total Ovules and Total Seeds per Fruit in Hibiscus.

Ovules	f	Total Seeds	Ovules	f	Total Seeds
23	—	—	*32*	81	1512
24	3	41	*33*	80	1575
25	2	26	*34*	80	1436
26	4	51	*35*	85	1746
27	18	285	*36*	54	1256
28	45	708	*37*	54	1129
29	107	1847	*38*	34	807
30	188	3727	*39*	27	691
31	125	2322	*40*	13	369

TABLE XIII.

Correlation for Ovules and Seeds per Locule in Hibiscus.

Seeds per Locule.

Ovules per Locule.	0	1	2	3	4	5	6	7	8	Totals
2	2	1	—	—	—	—	—	—	—	3
3	—	3	2	—	—	—	—	—	—	5
4	4	8	28	17	6	—	—	—	—	63
5	6	47	76	109	86	41	—	—	—	365
6	49	169	315	490	573	525	355	—	—	2476
7	30	97	167	221	237	244	235	103	—	1334
8	14	40	81	84	107	108	139	107	74	754
Totals	105	365	669	921	1009	918	729	210	74	5000

Comparing other constants for Hibiscus :—

Direct Intra-class for Ovules, $r = \cdot3843 \pm \cdot0081$,

Direct Intra-class for Seeds, $r = \cdot5557 \pm \cdot0066$,

Cross Intra-class for Ovules and Seeds, $r = \cdot1320 \pm \cdot0093$,

Organic for Ovules and Seeds, $r = \cdot2722 \pm \cdot0088$.

In all cases the probable error is calculated on the basis of the actual, not the weighted number of locules.

Illustration (III—Bb) 9. Cross Homotypic Correlation for Number of Ovules and Number of Seeds per Pod in Robinia.

From Tables VI, VII, and VIII *supra*, we deduce $S[\Sigma(o')\Sigma(s')] = 19070536$ which taken in conjunction with $S(o's') = S[\Sigma(o's')] = 141476$ taken from the organic correlation table for ovules and seeds in *Biometrika* (Vol. VI. pp. 441—442) and the physical constants $\bar{o}$, $\bar{s}$, σ_o, σ_s, given under illustration (III—Ab) 5, gives

$$r_{o_1 s_2} = \{[S[\Sigma(o')\Sigma(s')] - S[\Sigma(o's')]\}/S[n(n-1)] - \bar{o}\bar{s}]/\sigma_o\sigma_s = \cdot383.$$

This may be compared with $r_{o_1 o_2} = \cdot452$ and $r_{s_1 s_2} = \cdot449$. The discussion of the biological significance of the results from this and the preceding illustration must be reserved.

Problem IV. To Determine Direct or Cross Inter-Class Correlations from the First Two Moments of the Individual Classes.

Let x be the measure of a character in an individual of one class of p members and y be the measure of the same or a different character in an individual of another class of q members associated with the first for some logical (*e.g.*, biological, or sociological) reason. The coefficient calculated from a table in which every x of a first class is compared with every y in the second (associated) class may be designated as an inter-class coefficient of correlation.

The number of entries in an inter-class correlation surface will be $S(pq)$, where S indicates a summation of classes. $\Sigma(x')/p$, $\Sigma(x'^2)/p$, $\Sigma(y')/q$, $\Sigma(y'^2)/q$ are the

first two moment coefficients of individual classes, $[\Sigma(x')\Sigma(y')]/pq$ the product moment coefficient for an associated pair of classes and

$$S[\Sigma(x')\Sigma(y')]/S(pq), \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(xiii)}$$

the rough product moment coefficient for the whole population.

For every first class of p individuals there is an associated second class of q individuals. Hence, the individuals of the first class are always weighted* in a q-fold manner and those of the second class in a p-fold manner. The population constants weighted for the calculation of r are given by the rough moment coefficients about 0 as origin,

$$S[q\Sigma(x')]/S(pq), \quad S[q\Sigma(x'^2)]/S(pq), \ldots\ldots\ldots\ldots\ldots\ldots\text{(xiv)}$$
$$S[p\Sigma(y')]/S(pq), \quad S[p\Sigma(y'^2)]/S(pq). \ldots\ldots\ldots\ldots\ldots\ldots\text{(xv)}$$

Since x and y may be measures of the same or different characters it is clear that the formula is the same for direct or cross inter-class correlation.

Illustration (IV) 10. *Racial Heterogeneity and Homogamy in Man.*

It has sometimes been suggested that homogamy for physical and mental characters in man is due to (*a*) the existence in the population of numerous local races, (*b*) the excessive frequency of intra-racial marriages, attributable to propinquity merely, and (*c*) the pooling of records from many local races in the same correlation surface.

A study of the literature of assortative mating convinces one that so simple an explanation is inadequate. Nevertheless, it is very important to give full weight to any factors tending to bring about a spurious correlation for assortative mating.

One way of testing the question is to make random matings within the local races, pool the results for a series of districts, and determine the correlation†. The influence of the local differentiation can be read off in the inter-sexual correlation coefficient thus secured‡.

A convenient series of materials for stature is that gathered by Tocher§ for the counties of Scotland. To be sure, his measurements are on individuals who have become insane, but data for the normal population are lacking.

We may work from the table of constants (*Biometrika*, Vol. v. Supplement, Table XIX), taking populations of arbitrary size, say 100 males, m, and 100

* When it is possible to collect data so that either p or q, or both, are constant throughout the m pairs or classes the work is obviously considerably simplified. Unfortunately such cases are rare in practice.

† This was actually done for parish churchyards in the cooperative study of assortative mating for duration of life. Cf. *Biometrika*, Vol. II. p. 485, 1903.

‡ Of course our problem has some similarity to but differs fundamentally from that considered by Tschepourkowsky in his study of the resemblance between man and woman. Cf. *Biometrika*, Vol. IV. pp. 161—168, 1905.

§ Tocher, J. F., "The Anthropometric Characteristics of the Inmates of Asylums in Scotland," *Biometrika*, Vol. v. pp. 298—350, 1907.

females, f, from each district. Then for a district, $\Sigma(s') = 100\,\bar{s}$, the population means are given by $S[\Sigma(s')]/N$, the population standard deviations* by

$$\text{S.D.}^2 = S[100(\bar{s}^2 + \sigma_s^2)]/N - [S(100\,\bar{s})/N]^2,$$

where s represents stature in males or females as the case may be, the bars and σ's indicate county means and standard deviations and $N = S(n) = mn = 22 \times 100$.

The population constants are:

For Males:

$S(100\,\bar{s}) = 145080$, $N = 2200$,
$S(100\,\bar{s}^2) = 9567888$, $\bar{s} = 65{\cdot}945$,
$S(100\,\sigma_s^2) = 17335{\cdot}08$, S.D.^{2} = 8·116546,

For Females:

$S(100\,\bar{s}) = 134760$, $N = 2200$,
$S(100\,\bar{s}^2) = 8255232$, $\bar{s} = 61{\cdot}255$,
$S(100\,\sigma_s^2) = 13992{\cdot}05$, S.D.^{2} = 6·618921.

These will suffice for getting the correlations, since all classes comprise the same number of individuals and no change in the $\bar{s}$ or σ_s is introduced by weighting.

The totals of the correlation surface are $22 \times 100 \times 99 = 217800$ for the intra-patrial correlation for stature of random pairs of males and random pairs of females, and the rough product moment coefficients are given by

$$\{100\,S(100\,\bar{s}^2) - [S(100\bar{s}^2) + S(100\,\sigma_s^2)]\}/S[n(n-1)],$$

whence, for males, $r = {\cdot}019$,
for females, $r = {\cdot}029$.

But for the inter-sexual correlation between random pairs of men and women for the several counties, pooled together, there are mn^2, not $m[n(n-1)]$ combinations, since each male may be compared with all the females of the district, while in intra-sexual correlations the individual's own measure must be deducted. For random pairs of men and women we have, therefore, for the unadjusted product moment

$$S[\Sigma(s'_m)\,\Sigma(s'_f)] = 888716500, \quad N = 220000,$$

whence

$$r = (4039{\cdot}620454 - 65{\cdot}945455 \times 61{\cdot}254545)/2{\cdot}848955 \times 2{\cdot}572726 = {\cdot}022.$$

The result just deduced taken in comparison with that secured in a similar manner for the several parishes of the Wensleydale district†, seems to indicate that the geographical differentiation in the population plays a very small part in the production of the correlation between husband and wife.

* In getting $S[100(\bar{s}^2 + \sigma_s^2)]$ for the standard deviations we can save the labour of mental additions of large squares by taking separately $S(100\bar{s}^2)$ and $S(100\sigma_s^2)$. We have then only to multiply $S(100s^2)$ by 100 to get $S[100s]^2 = S[\Sigma(s')]^2$. $S\Sigma(s'^2)$ is of course given by the second moment calculated for the population S.D. Thus the squaring and summation can be quickly done simultaneously on any of the usual types of calculators.

† *Biometrika*, Vol. II. p. 485.

Problem V. To Determine Fractional Direct or Cross Inter-class Correlations from the First Two Moments of the Individual Classes.

Under (IV) every x of the first class is compared with every y of the second class. In actual practice, however, cases are frequent where all the possible comparisons are not made. Such relationships may be designated as fractional inter-class correlations. They are more difficult to determine than the simple inter-class constants but they are of very great importance in many cases. Of course the method is quite general, but for clearness I take the determination of the avuncular correlations as an illustration.

If x be the measure of a character in a parental array, family or sibship of p individuals and y the measure of the same or a different character in the offspring array (or family or families) of q individuals, then the inter-class correlation involving the comparison of every x with every y in the related classes of the population of m classes may be designated as an ascendant (or, if one chooses, descendant) correlation of the first order*. From such a table, actually formed by the method described under (I) or only expressed algebraically as under (IV), one may easily derive the avuncular correlation—*i.e.*, that between "uncles (aunts)" and "nephews (nieces)"—as follows:

In such an ascendant correlation, the offspring individuals are associated with all the members of the parental array, both their own parents and their parent's siblings, or there are $S(pq)$ combinations.

Hence it is given by formulae (xiii—xv) under (IV). To obtain the avuncular correlation we have only to deduct from the five fundamental summations of the ascendant correlation those for the relationships between (weighted) individual parents and their $S(q)$ individual offspring, and proceed to the correlation of r on the basis of $S(pq-q)$ instead of $S(pq)$ individuals.

But the direct parental correlation is practically always wanted on its own account. It is most easily obtained from an ordinary or condensed correlation table, or by the method described under (II). Designating by the subscript i the measures entering into the correlations for individual parents (weighted with their offspring) and their offspring, we have for the avuncular relationship (the fractional inter-class correlation) by simple subtraction,

$$\frac{S[\Sigma(x')\,\Sigma(y')] - S(x_i'y_i')}{S(pq) - S(q)}, \quad \text{.....(xvi)}$$

for the product moment coefficient, and

$$\frac{S[q\Sigma(x')] - S(x_i')}{S(pq) - S(q)}, \quad \frac{S[q\Sigma(x'^2)] - S(x_i'^2)}{S(pq) - S(q)}, \quad \text{.....(xvii)}$$

$$\frac{S[p\Sigma(y')] - S(y_i')}{S(pq) - S(q)}, \quad \frac{S[p\Sigma(y'^2)] - S(y_i'^2)}{S(pq) - S(q)}, \quad \text{.....(xviii)}$$

for the moment coefficients.

* If correlation between parental and offspring arrays be designated as of the first order, that between grandparental and grandoffspring arrays is of the second order, and so on.

TABLE XIV. *Weight of Seeds produced by Parental and Offspring Plants in Garden Beans.*

TABLE XIV. *Weight of Seeds produced by Parental and Offspring Plants in Garden Beans.*

	Weight for Parental Plants														
Plant	3	4	5	6	7	8	9	10	11	12	13	14	p	$\Sigma(x')$	$\Sigma(x'^2)$
1	1	–	–	–	–	5	10	6	1	–	–	–	23	204	1860
2	–	–	2	–	4	12	15	3	–	–	–	–	36	299	2529
3	–	–	–	–	1	3	10	9	2	–	–	–	25	233	2193
4	–	–	–	1	3	6	8	1	–	–	–	–	19	157	1315
5	–	1	–	2	–	2	6	21	10	–	–	–	42	406	4012
6	–	–	–	–	2	13	26	7	–	–	–	–	48	422	3736
7	–	–	–	–	–	2	8	15	15	–	–	–	40	403	4091
8	–	–	–	–	7	18	15	2	–	–	–	–	42	348	2910
9	–	–	–	1	–	5	9	13	12	5	–	–	45	449	4557
10	–	–	–	1	–	11	17	11	–	–	–	–	40	357	3217
11	–	–	–	–	–	3	7	7	13	2	–	–	32	324	3320
12	–	–	–	–	2	9	20	1	–	–	–	–	32	276	2394
13	–	–	1	10	18	8	1	–	–	–	–	–	38	264	1860
14	–	–	–	–	–	6	8	22	4	–	–	–	40	384	3716
15	–	–	–	1	2	6	12	17	2	–	–	–	40	368	3432
16	–	–	–	–	–	2	–	1	12	21	6	1	43	502	5914
17	–	–	1	1	5	11	2	3	–	–	–	–	23	182	1472
18	–	–	–	–	–	–	1	10	3	–	–	–	14	142	1444
19	–	–	–	2	2	14	5	–	–	–	–	–	23	183	1471
20	–	–	–	–	–	1	4	4	9	4	–	–	22	231	2453
21	–	–	–	3	5	9	6	3	2	–	–	–	28	231	1957
22	–	–	–	–	2	12	16	5	4	–	–	–	39	348	3146
23	–	–	–	–	3	11	16	1	–	–	–	–	31	263	2247
24	–	–	–	–	1	6	17	12	2	–	–	–	38	350	3252
25	–	–	–	–	–	1	19	20	1	–	–	–	41	390	3724
26	–	–	–	1	–	3	8	15	8	3	1	–	39	389	3945
27	–	–	–	–	4	14	19	4	–	–	–	–	41	351	3031
28	–	–	–	3	9	10	14	2	3	–	–	–	41	340	2886
29	–	–	2	1	1	7	14	13	3	–	–	–	41	368	3380
30	–	–	–	–	2	27	11	1	–	–	–	–	41	339	2817
31	–	–	–	–	–	1	3	19	13	4	–	–	40	416	4356
32	–	–	–	1	–	7	8	14	8	2	–	–	40	386	3788
33	–	–	–	–	1	3	15	23	2	–	–	–	44	418	3998
34	–	–	–	–	–	1	7	25	6	2	–	–	41	411	4145
35	–	–	–	–	–	1	–	13	24	2	1	–	41	439	4725
36	–	–	–	–	1	13	22	5	–	–	–	–	41	359	3163
37	–	–	–	–	1	–	6	4	13	7	–	–	31	328	3516
38	–	–	–	–	3	4	8	6	4	1	–	–	26	241	2279
39	–	–	1	–	–	4	19	12	6	–	–	–	42	394	3746
40	–	–	–	–	–	–	4	16	14	3	–	–	37	386	4050

	Weight for Offspring Plants														
Line	3	4	5	6	7	8	9	10	11	12	13	14	15	q	$\Sigma(y')$	$\Sigma(y'^2)$
1	–	–	–	2	2	9	15	5	1	1	–	–	–	35	306	2726
2	–	–	–	2	3	11	13	12	2	–	–	–	–	43	380	3418
3	–	1	2	8	7	11	5	2	2	–	–	–	–	38	286	2248
4	–	–	2	5	10	17	10	6	–	–	–	–	–	50	396	3218
5	–	–	2	4	4	8	12	5	4	1	–	–	–	40	340	3002
6	–	–	6	10	13	18	10	3	–	–	–	–	–	60	445	3409
7	–	–	1	2	5	12	18	5	–	1	–	–	–	44	372	3212
8	1	–	1	1	7	10	9	9	2	3	–	–	–	43	372	3356
9	1	3	–	1	2	5	11	9	2	–	–	–	–	34	286	2544
10	–	–	1	1	2	5	10	5	5	–	–	–	–	29	260	2394
11	–	–	–	6	12	11	9	5	1	1	–	–	–	45	362	3002
12	–	–	3	6	7	15	8	4	1	–	–	–	–	44	343	2763
13	–	–	2	8	14	8	12	1	1	–	–	–	–	46	349	2729
14	–	1	3	4	13	10	4	5	–	–	–	–	–	40	300	2336
15	–	1	1	5	5	10	12	6	1	–	–	–	–	41	333	2799
16	–	–	–	–	–	3	9	12	5	4	10	1	1	45	487	5413
17	–	1	2	2	6	5	10	2	3	–	–	–		31	251	2125
18	–	–	–	–	1	1	2	1	–	–	–	–	–	5	43	375
19	–	–	4	4	11	8	7	2	–	–	–	–	–	36	268	2062
20	–	–	–	5	2	10	9	14	8	2	–	–	–	50	457	4303
21	–	–	1	1	10	13	10	2	–	1	–	–	–	38	307	2537
22	–	–	1	3	7	15	13	7	4	–	–	–	–	50	423	3673
23	–	–	–	3	14	15	12	5	–	–	–	–	–	49	394	3226
24	–	–	–	1	8	14	12	9	2	1	–	–	–	47	406	3582
25	–	–	1	3	19	11	8	3	1	–	–	–	–	46	357	2837
26	–	–	1	1	2	1	11	16	12	3	–	1	–	48	474	4794
27	–	–	–	1	4	12	16	7	1	1	1	–	–	43	380	3430
28	–	–	–	1	4	4	16	10	2	–	–	–	–	37	332	3026
29	–	–	–	1	5	13	6	8	6	4	–	–	–	43	393	3701
30	–	–	–	1	5	9	14	9	6	–	–	–	–	44	395	3617
31	1	–	1	6	8	12	6	4	6	1	–	–	–	45	368	3166
32	–	–	–	–	6	10	9	7	1	–	1	–	–	34	297	2653
33	–	–	1	4	7	21	10	5	–	–	–	–	–	48	386	3166
34	–	–	–	1	9	15	11	7	1	–	–	–	–	44	369	3149
35	–	–	4	3	9	9	8	10	2	1	–	–	–	46	379	3259
36	–	–	–	1	2	14	9	9	6	–	–	–	–	41	369	3385
37	–	–	–	2	6	13	7	7	–	4	–	–	–	39	339	3041
38	–	–	1	2	10	13	14	2	2	1	–	–	–	45	371	3139
39	–	–	–	–	7	15	19	4	–	–	–	–	–	45	380	3242
40	–	–	–	–	2	10	10	7	8	–	–	–	–	37	342	3216

These formulae lend themselves readily to practical manipulation. The rough moments for the parental-offspring surface are generally available; the others are obtained by rapid machine calculation.

Illustration (*V*) 11. *Avuncular Correlation in Garden Beans.*

As an illustration I take the calculation of the "avuncular" correlation in a series of forty families of garden beans—The Navy H series of former papers*. Table XIV gives the necessary data. The first part shows the weight of the seeds from the 40 parents, seriated individually with the sums and sums of squares of their values. Only a portion of the seeds (roughly 10) from each of these mothers were planted, and give the offspring arrays shown with their summations in the second part of the table.

The direct parental correlation†—that between the weight of the individual seed planted and the weight of the seeds which it produces—is given in Table XV.

TABLE XV.

Seed Weight in Garden Beans.

Offspring Weight.

Parental Weight.	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	Totals
5	—	—	—	—	1	4	—	2	1	—	—	—	—	8
6	—	—	2	6	8	4	4	4	—	—	—	—	—	28
7	—	—	1	7	21	18	21	4	3	4	—	—	—	79
8	—	2	10	21	62	103	100	55	19	4	3	—	—	379
9	1	1	15	29	74	137	134	72	23	3	—	—	—	489
10	1	3	7	30	71	102	77	54	25	5	—	—	—	375
11	1	—	6	18	31	51	66	47	22	12	2	2	—	258
12	—	1	—	—	2	7	14	10	3	2	3	—	—	42
13	—	—	—	—	—	—	—	3	2	—	4	—	1	10
Totals	3	7	41	111	270	426	416	251	98	30	12	2	1	1668

* *American Naturalist*, Vol. XLVI. pp. 313—343, 512—525, 656—674, 1912; Roux's *Archiv f. Entwicklungsmechanik der Organismen*, Bd. XXXV. S. 500—522, 1912; *Biometrika*, Vol. IX. pp. 11—21.

† The Editor has called my attention to the possibility of some misunderstandings which might be introduced by this illustration and I am glad to add a word of explanation concerning it.

The chief question which is likely to be raised is: "What constitutes direct parental inheritance in a character like seed weight?" Some rather complicated biological questions are involved. The coats of the seed are a part of the plant individual which produces them—are in fact strict homotypes in Pearson's sense of the term. But the embryo—the cotyledons, hypocotyl and the plumule, *the elements which constitute the major part of the weight of the seed*—is strictly speaking a daughter plant. Hence an intra-individual correlation for seed weight is not a true homotypic correlation but a fraternal or sororal correlation. Thus from the embryological or genetic standpoint the correlation between the weight of the individual seed planted and the weights of the seed borne by the plant into which it develops is the true parental correlation.

There are, however, two important modifying conditions. First, the correlation is between two individuals in an embryonic stage, not in the adult condition. It is somewhat analogous to the correlation between the larval characteristics of two successive generations of moths, and resembles still more closely the coefficient measuring the resemblance between a parent's weight at birth and

Designating the parental generation seeds by x and the offspring seeds by y, I find from Table XV,

$$\Sigma(x') = 15416, \qquad \Sigma(y') = 14097,$$
$$\Sigma(x'^2) = 145400, \qquad \Sigma(y'^2) = 123273,$$
$$\Sigma(x'y') = 130794,$$

whence, with Sheppard's correction,

$$r = (130794/1668 - 9{\cdot}242206 \times 8{\cdot}451439)/1{\cdot}291727 \times 1{\cdot}547424 = {\cdot}1519.$$

From Table XIV I find for the ascendant-descendant correlation

$$S(pq) = 60756,$$
$$S[q\Sigma(x')] = 564066, \qquad S[p\Sigma(y')] = 514990,$$
$$S[q\Sigma(x'^2)] = 5351080, \qquad S[p\Sigma(y'^2)] = 4518074,$$
$$S[\Sigma(x')\Sigma(y')] = 4798171.$$

These give

$$r = (4798171/60756 - 9{\cdot}284120 \times 8{\cdot}476364)/1{\cdot}340412 \times 1{\cdot}559539 = {\cdot}1334.$$

But obtaining the summations about 0 for the avuncular relationship by simple subtraction I get for the population N

$$S[q(p-1)] = S(pq) - S(q) = 60756 - 1668 = 59088,$$

and for physical constants, for "aunts"

$$\bar{x} = (564066 - 15416)/59088 = 9{\cdot}285303,$$

$$\sigma_x = \sqrt{(5351080 - 145400)/59088 - (9{\cdot}285303)^2 - {\cdot}083333} = 1{\cdot}341743,$$

and for "nieces"

$$\bar{y} = (514990 - 14097)/59088 = 8{\cdot}477068,$$

$$\sigma_y = \sqrt{(4518074 - 123273)/59088 - (8{\cdot}477068)^2 - {\cdot}083333} = 1{\cdot}559872,$$

and for the relationship between them

$$r = [(4798171 - 130794)/59088 - \bar{x}\bar{y}]/\sigma_x\sigma_y = {\cdot}1329.$$

a child's weight at birth. Second, all the seeds produced by the same plant are under closely similar environmental conditions. Thus while they are (so far as the embryo to which weight is chiefly due) sister seeds, they are far more nearly alike than would be expected on the basis of heredity alone, for all are borne in and nourished by the maternal tissues.

Under these circumstances one may consider either (*a*) the correlation between the individual seed planted and the individual seed produced, or (*b*) the correlation between the average character of all (or of a representative sample) of the seeds of a parental and filial individual to be the true correlation.

If the latter view is taken one considers the characteristics of the seeds to be determined exclusively by the plant on which they are borne (the parent plant).

If the former alternative be adopted one neglects for the moment the important environmental factor introduced by the fact that the whole array of parental seeds are subjected to the limited environment of one plant while the offspring array (produced by any single plant) is subjected to the environment of another plant.

It has seemed to me safest to follow strictly the biological homologies in terminology.

I note that the parental relationship is the highest and the avuncular the lowest. These results cannot be discussed in detail until the final memoir from which they are abstracted is published, but it seems to me that they agree with Hanel's data for *Hydra* as analyzed by Pearson* in affording no support to Johannsen's conclusions concerning the ineffectiveness of selection within the pure line.

If one desires a check, or if linearity of regression must be tested, one may proceed by the method already described for the formation of condensed correlation tables †.

Either ascendant or descendant seeds may be taken as the "first" or subject character. Since they are quickly formed, both have been drawn up for the convenience of the reader and appear as Tables XVI—XVII. In them, the first two columns give the reduced tables for parents and offspring (or offspring and parents), the second two give the frequencies for the ascendants weighted with their descendants (or the descendants weighted with their ascendants) and the totals of the associated arrays. The final two columns are obtained by subtracting the first pair from the second, and give the avuncular relationship desired. Naturally, the final summations of these columns may be subtracted if linearity tests only are not desired. All the above constants may be checked directly from these tables.

TABLE XVI.

Weight of Ancestral Seed	Parental Correlation		Ascendant-Descendant Correlation		Avuncular Correlation	
	Frequency of Actual Parents Weighted with their Offspring	Total Offspring Weight	Weighted Frequency of Descendant Seeds	Total Weight of Weighted Descendant Seeds	Weighted Frequency of Nepotic Seeds	Total Weight of Weighted Nepotic Seeds
3	—	—	35	306	35	306
4	—	—	40	340	40	340
5	8	70	294	2526	286	2456
6	28	210	1147	9313	1119	9103
7	79	648	3389	27780	3310	27132
8	379	3188	11510	96824	11131	93636
9	489	4085	18095	151467	17606	147382
10	375	3111	15184	127618	14809	124507
11	258	2270	8247	71591	7989	69321
12	42	396	2406	22963	2364	22567
13	10	119	364	3775	354	3656
14	—	—	45	487	45	487
Totals	1668	14097	60756	514990	59088	500893

* *Biometrika*, Vol. VII. pp. 372—381, 1910.

† *American Naturalist*, Vol. XLVI. pp. 477—486, 1912.

TABLE XVII.

Weight of Offspring Seed	Parental Correlation		Ascendant-Descendant Correlation		Avuncular Correlation	
	Actual Frequency	Total Weight of Weighted Parental Seeds	Weighted Frequency of Ascendant Seeds	Total Weight of Weighted Ascendant Seeds	Weighted Frequency of Avuncular Seeds	Total Weight of Weighted Avuncular Seeds
3	3	30	127	1213	124	1183
4	7	67	263	2514	256	2447
5	41	370	1473	13393	1432	13023
6	111	1012	3901	35562	3790	34550
7	270	2437	9672	88297	9402	85860
8	426	3892	15421	142308	14995	138416
9	416	3841	15190	139924	14774	136083
10	251	2366	9333	88150	9082	85784
11	98	939	3642	34725	3544	33786
12	30	293	1098	10830	1068	10537
13	12	134	511	5757	499	5623
14	2	22	82	891	80	869
15	1	13	43	502	42	489
Totals	1668	15416	60756	564066	59088	548650

III. RECAPITULATION.

The term intra-class is suggested for the correlation describing the degree of resemblance of the individuals of the series of sub-groups or sub-classes into which a general population may be divided for some logical (*e.g.*, biological, sociological) reason. The term inter-class is applied to those correlations which describe the degree of interdependence of variables belonging to the logically related sub-classes of different populations. Such coefficients have a very wide but hitherto little realized range of usefulness.

Generally, their determination requires the comparison of each individual with the array of individuals constituting its own or its associated class. Heretofore the use of such coefficients has been limited, indeed almost precluded, by the excessive labour of forming the weighted tables. Methods for the rapid formation of the tables by the aid of mechanical calculators have been described, and formulae are now given by which such correlations can be determined without the formation of tables at all.

The labour of calculation may thus be reduced to a small fraction of that formerly required. The formulae present numerous opportunities for checking the arithmetic, but of course certain errors may be more easily detected when tables are used. Furthermore the tables, full or condensed, should be formed in

a certain number of cases for the purpose of testing the form of the regression curve.

Finally, in emphasizing the use of Intra-class and Inter-class Coefficients it may not be out of place to warn the reader that, as in the case of many other statistical relationships, the *raw or uncorrected* values may give quite erroneous impressions of the biological relationships under investigation. Some such cases will be discussed later. In the meantime, the purpose of this paper will have been fulfilled if the range of illustrations proves suggestive of wider application and if the formulae prove as useful to other biologists as they have to workers in my laboratory, where they have been very extensively used and have become indispensable tools.

In conclusion I take great pleasure in thanking most heartily the Editor of this Journal for the kindly criticisms and suggestions which have materially improved the manuscript.

A SECOND STUDY OF THE WEIGHT, VARIABILITY AND CORRELATION OF THE HUMAN VISCERA.

By M. GREENWOOD, Junr., and J. W. BROWN.

(*From the Statistical Laboratory of the Lister Institute.*)

In 1904, one of us published an account of certain applications of biometric methods to data obtained from the pathological department of the London Hospital*. The object of that essay was to throw light upon the mean values, variabilities and correlations of the human visceral organs, in the hope of (*a*) Placing on record results comparable with the numerous studies of anthropologists which deal with other organs or dimensions: (*b*) Providing materials for the study of the changes produced by various diseases in the absolute measures and inter-relations of the organs observed and, therefore, *pro tanto*, illustrating the work of selection upon the human species.

In the paper cited, attention was directed to the specialised characters of a "General Hospital Population" and it was pointed out that results obtained from such a population could not be generalised without inquiry as applicable to the race at large. It was also shown that groups selected upon various principles within the "General Hospital Population" exhibited marked deviations from the prevalent type, a selection of the more healthy organs being attended by a rise in correlation and a fall in variation, while a group characterised by a preponderance of specifically diseased organs exhibited changes in the opposite sense.

The difficulty which had to be faced in that investigation was the task of ascertaining the characteristics of a healthy "General Hospital Population." By this expression we define the class of persons of the physical, racial and economic type to which hospital patients conform but who are not suffering from any disease likely to cause death or seriously affect health. The nature of the material available in 1904 did not permit of such a selection being made and all that could be done was to choose from the data those organs which, so far as the records showed, were not obviously diseased. Such cases formed the normal or "healthy" material

* *Biometrika*, Vol. III. p. 65.

of the earlier paper. In Table I we have grouped the results obtained from such data; the figures relating to males have already been published, those dealing with females are based upon the manuscript records, and are given for the sake of comparison. It will be noticed that in two cases the correlations for the female data

TABLE I.

A. *Constants calculated from Old Data. Healthy Organs.*

Organ	Sex	Mean	Standard Deviation	Correlation
Heart ...	M.	11·04 ± ·07 ozs.	1·923 ozs.	·2780 ± ·0329
Liver ...	M.	60·44 ± ·32 „	8·948 „	[H. and L.]
Heart ...	F.	10·12 ± ·11 „	3·087 „	·2163 ± ·0325
Liver ...	F.	55·23 ± ·15 „	4·298 „	[H. and L.]
Heart ...	M.	11·25 ± ·06 „	2·073 „	·2654 ± ·0276
Spleen ...	M.	5·22 ± ·06 „	1·996 „	[H. and S.]
Heart ...	F.	10·02 ± ·10 „	3·422 „	·1881 ± ·0295
Spleen ...	F.	6·07 ± ·10 „	3·197 „	[H. and S.]
Heart ...	M.	11·24 ± ·06 „	1·946 „	·4004 ± ·0279
Kidneys ...	M.	12·01 ± ·07 „	2·016 „	[H. and K.]
Heart ...	F.	9·45 ± ·09 „	2·445 „	·4465 ± ·0292
Kidneys ...	F.	10·58 ± ·10 „	2·620 „	[H. and K.]

B. *Relative Variability of Healthy Organs.*

Organs	Sex	Coefficient of Variation	
Hearts with Livers ...	M.	17·42	mean 17·71
Hearts with Spleens ...	„	18·42	
Hearts with Kidneys ...	„	17·30	
Livers	„	14·80	
Spleens	„	38·21	
Kidneys	„	16·80	
Hearts with Livers ...	F.	30·49	mean 30·17
Hearts with Spleens ...	„	34·17	
Hearts with Kidneys ...	„	25·86	
Livers	„	7·78	
Spleens	„	52·69	
Kidneys	„	24·76	

are slightly smaller, in one instance perhaps significantly smaller, than the male values, while the relative variabilities are in two cases higher among the females.

It was to be anticipated, from the nature of the case, that the results just given would be only rough approximations to the desired values descriptive of a healthy "General Hospital Population." This anticipation has been confirmed by other work. Thus Pearson has shown that the form of frequency distribution indicated by the graph of "healthy" hearts would suggest arbitrary limitation at each end of the distribution, some small and many large hearts having been unjustifiably

classed as abnormal*. It therefore seemed desirable to re-investigate this particular problem and a special motive for doing so now is that one of us hopes shortly to collaborate with Dr Mott in the reduction of similar but more extensive data collected in Claybury Asylum. To make this latter inquiry complete, some comparison of biometric constants derived from an insane population with those yielded by sane stock is essential. The sane population as a whole not being available, and the economic strata which provide general hospital and county asylum patients being similar, it seemed probable that an extension of the earlier inquiry would be of value. Under these circumstances recourse was once more had to the pathological department of the London Hospital. We took this step with the more confidence because we knew that since the date of the first investigation the pathological records of the London Hospital had been enormously improved, under the supervision of Dr H. M. Turnbull, Director of the Pathological Institute.

Dr Turnbull kindly supplied us with data prepared in accordance with his instructions and we desire to express our gratitude to him not only for placing the material at our disposal but for much friendly advice and criticism throughout the inquiry.

The data provided by Dr Turnbull include, with the exception of the weight of the spleen, all the measurements recorded in the former series and in addition the weight of the brain (in most cases), and the weight of the whole body and its length. We must, however, remark that the last mentioned datum, although included in one of our tables, has been shown to be unreliable, so that no sound conclusions can be based upon it. We shall refer to this point later.

With respect to the methods by which these data were prepared, we have somewhat exact details. Dr Turnbull permits us to quote the following passage from a private letter addressed to one of us.

"Before the bodies are put on the P.M. tables they are weighed and measured and the results are entered by the porters upon the tops of the sheets for the description of the necropsy. Each organ after it has been removed, cut and described is placed in the tray at the end of the table and left there until Dr Bartlett or I have gone through the case dictating the diagnosis of the case as a whole and of each organ. So soon as most of the organs have been completely separated the porters lift them from the trays, weigh them and write down the weights on the large slate in the P.M. room. Occasionally an assistant places an organ in the tray before slicing into it; it may therefore be weighed before it is sliced, but this is exceptional. The organs are almost always completely separated and therefore weighed before Dr Bartlett and I go through the case. In special circumstances they are placed in the trays without separation, e.g., in disease of the bile ducts the liver, pancreas, stomach and duodenum would be placed together in the tray without separation until Dr Bartlett or I examined them. Such organs would be

* *Biometrika*, Vol. IV. p. 183.

weighed later than the others. In cases of accident it would be extremely unlikely that such a proceeding would ever be necessary. You may take it then that in the cases sent to you the organs were weighed almost immediately after removal and examination by the assistant."

This material although naturally less extensive than that previously used is far more reliable. Dr Turnbull knew that we wished to study healthy organs and consequently the data received by us formed a selection not a random sample of the "General Hospital Population." We have, however, carried the process of selection yet further. We chose from the data all the males at ages 25—55 and rejected from this number (1) all that had died of a wasting disease, such as Cancer or Tuberculosis; (2) all cases in which a possibly pathological condition of the heart was noted, whatever the weight of the organ might be; (3) cases in which Syphilis might be suspected (those with record of aneurism in particular); (4) all cases with no recorded body-weight.

The cases without recorded body-weight have not been considered at all, but those rejected from the series on account of (1), (2) or (3) were subsequently added to the remainder and the constants of the whole series ultimately calculated. Our work therefore falls into two parts, the first being an analysis of some 78 doubly selected cases, the second a reduction of about 100 records selected also but not so stringently. An examination of the data which are published as an appendix to this memoir will enable the reader to appreciate our method; it may be remarked that certainly one and possibly two cases not admitted to the "double selection" should have figured there (one was left out by mistake), while some of those admitted, in particular the epileptics, ought possibly to have been omitted. On the whole, however, we think the "double selection" conforms pretty well to the type we had in mind. Needless to say, it falls far short of the ideal, since, not to mention other points, we have not been able to take account of occupation or race in view of the paucity of our material. It may also be mentioned that we have other data relating to persons outside the limits of age here adopted; the analysis of these cases will be dealt with in another communication.

The non-medical reader will perhaps wonder how it is that we think it worth while to deal with so few cases, and may object that the London Hospital is only one of a number of great medical charities and that the material from all of these should be pooled and treated as a whole. This would be so obviously the proper course were it practicable that we may be allowed to point out the difficulties in the way of its adoption. The effective absence of coordination between the medical schools, the diverse systems in force and the contempt of statistical data which up to recent times characterised all but a minority of the hospital staffs, would render any individual attempt to deal with combined records a troublesome and possibly futile undertaking. We are not speaking without knowledge of the statistical systems in vogue at a large hospital when we say that the present state of affairs is unsatisfactory. Every year tons of paper and gallons of ink are devoted to recording the experiences, medical, surgical and pathological, of the great teaching

institutions. An extremely small percentage of the results have any value at all, while even that residuum is not readily accessible. Comparatively little trouble and some expense would notably diminish the output of waste-paper and increase the production of valuable records.

Hospital administrators pay little attention to the advice of private enthusiasts —and quite properly since compliance with requests for innovation might turn hospitals into happy hunting grounds for faddists of all kinds. There are we think but two ways in which genuine statistical reforms are likely to be brought about. One is through Government or Municipal action, a process which does not (if we may judge from the report of the recent Royal Commission on the Record Office) necessarily lead to the best results. The second is through the realisation on the part of leading physicians and surgeons of the importance which attaches to organised statistical data. Perhaps when consumption has been "conquered" and the infant death rate reduced 80%, medical protagonists may be induced to turn their attention to a humbler but still important reform. The question is really of more importance than might be inferred from the subject of this paper. The problem with which we are immediately concerned here is not of momentous interest, but the difficulties under which we labour apply to all statistical investigations of a "General Hospital Population." Since every youth destined to earn his bread as a doctor acquires his first and therefore his most vivid impressions of the phenomena of disease among a "General Hospital Population," it is of importance to all his future patients that these impressions should be controlled, checked and, if possible, corrected by any available method. One such method, the statistical realisation of precisely what a "General Hospital Population" is, and how it may be presumed to differ from the nation at large, is at present impossible owing, in great measure, to obstacles which can be removed. This is now the opinion of a small minority; if it is ever adopted by a majority, those who, having the means of reform at their command, neglect to adopt them will find some difficulty in explaining their position.

TABLE II.

Constants calculated from New Data (Select Cases). Healthy Organs. Males (25—55).

Variable	Mean	Standard Deviation	Coefficient of Variation
Heart	11·96 ± ·14 ozs.	1·896	15·86
Body-weight	129·82 ± 1·80 lbs.	23·605	18·18
Kidneys	10·67 ± ·16 ozs.	2·049	19·21
Liver	57·39 ± ·86 „	11·263	19·63
Age	41·27 ± ·66 yrs.	8·632	20·92
Brain	49·31 ± ·36 ozs.	4·558	9·24
["Body-length"] ...	[68·99 ± ·20 ins.]	[2·548]	[3·69]

We now pass to the results of our investigation and begin with the specially selected series, the chief constants of which are given in Tables II and III. All the mean values which can be compared with those set out in Table I differ significantly therefrom; the heart is heavier, the other organs lighter than in the first series. It is doubtful whether the changes in relative variability of the heart and kidneys are significant, the difference in the latter case being only $2{\cdot}41 \pm 1{\cdot}12$.

TABLE III A.

Total Correlations.

	Heart	Body-weight	Kidneys	Liver	Brain	["Body-length"]	Age
Heart ...	1	·65 ± ·04	·56 ± ·05	·52 ± ·06	·08 ± ·08	[·42 ± ·06]	·04 ± ·08
Body-weight ...	·65 ± ·04	1	·37 ± ·07	·57 ± ·05	·25 ± ·07	[·52 ± ·06]	− ·03 ± ·08
Kidneys ...	·56 ± ·05	·37 ± ·07	1	·43 ± ·06	·08 ± ·08	[·28 ± ·07]	− ·05 ± ·08
Liver ...	·52 ± ·06	·57 ± ·05	·43 ± ·06	1	·13 ± ·08	[·41 ± ·06]	− ·16 ± ·07
Brain ...	·08 ± ·08	·25 ± ·07	·08 ± ·08	·13 ± ·08	1	[·27 ± ·07]	− ·08 ± ·08
["Body-length"]	[·42 ± ·06]	[·52 ± ·06]	[·28 ± ·07]	[·41 ± ·06]	[·27 ± ·07]	[1]	[− ·20 ± ·07]
Age ...	·04 ± ·08	− ·03 ± ·08	− ·05 ± ·08	− ·16 ± ·07	− ·08 ± ·08	[− ·20 ± ·07]	1

TABLE III B.

Partial Correlations.

Variables	"Constants"	Correlation
Heart and Body-weight	Kidneys and Liver	·49 ± ·06
Heart and Kidneys	Body-weight and Liver	·41 ± ·06
Heart and Liver	Body-weight and Kidneys	·13 ± ·08
Body-weight and Kidneys	Heart and Liver	− ·07 ± ·08
Body-weight and Liver	Heart and Kidneys	·36 ± ·07
Kidneys and Liver	Heart and Body-weight	·21 ± ·07

The liver, on the other hand, seems to be definitely more variable in the present series. Our finding, so far as the heart is concerned, confirms the remark of Pearson already cited. With respect to the correlations, those which have corresponding entries in Table I are larger than these, the coefficient involving the liver being significantly increased. Some of the other constants, while not matched in Table I, may be compared with the reductions of Blakeman* and Pearl†, viz. brain- and body-weights. Our mean brain is heavier than that deduced by Blakeman from the Middlesex Hospital data and near Pearl's figure

* J. Blakeman, "A Study of the Biometric Constants of English Brain Weights," *Biometrika*, Vol. IV. p. 124, 1905.

† R. Pearl, "Variation and Correlation in Brain Weight," *ibid.* p. 13.

for Bohemian cases. The mean body-weight is greater than Pearl's figure and the coefficient of variation between that of Pearl and Pearson*.

Since Pearl and Blakeman did not restrict their inquiry to persons between 25 and 55 years of age, any comparison of our results with theirs must be of doubtful validity. Similarly we cannot control the constants involving age by comparisons with the work of other biometricians. In the first study, the correlation between age in years and "healthy" heart weight for males was given as $\cdot 136 \pm \cdot 025$ and from the same data we find in the case of females $r = \cdot 155 \pm \cdot 029$, in good agreement with the former value. Our present results cannot be said to differ significantly from the old values and we may quote a passage from the other memoir: "When we remember that the healthy heart is on the average much smaller than the heart in disease, and that sickness on the average increases continuously with age, we shall probably lay less stress on the general *a priori* idea that the weight of the adult heart increases very sensibly with age alone†." We see no reason to modify this view; further the recorded ages are likely to be subject to a considerable observational error in this class of material.

The general conclusion therefore both of the present and the first study is that age alone is not *proved* to be sensibly correlated with the weights of the viscera in an adult healthy "General Hospital Population."

The correlations involving body-weight are the most interesting in our new series since, with the exception of Pearl's results, they are so far as we are aware the first reductions of this variable in its association with the visceral weights which have been published. It may be freely admitted that the weight of a corpse must be so appreciably affected by the circumstances immediately preceding death that it cannot correspond at all closely to the weight during life. The force of this objection is diminished by the large percentage of violent deaths to be found in our series, since these cases would not be affected by the rapid wasting so often associated with a fatal illness.

Chiefly for this reason, we are not without hope that the present calculations throw some light upon the true correlation between heart weight and body-weight‡. One inference seems clear enough, viz. that no opinion ought to be ventured as to whether the weight of a heart is or is not normal without taking into account not only that of the other organs but also the body-weight. This leads to the question as to whether a formula of the nature of a regression equation might appropriately be employed to connect heart weight with other variables. In selecting variables upon which to base a prediction of the heart weight, the ideal is that each member of the set shall be highly correlated with the heart and that the correlation of the chosen variables one with another shall be low. For the purposes of a first trial, we decided to found the prediction

* K. Pearson, "The Chances of Death, etc.," Vol. I. pp. 293, etc.

† Greenwood, *op. cit.* p. 69.

‡ It is also to be remembered that there must be an appreciable *post mortem* loss of weight owing to evaporation in the cold chamber.

upon the weight of the whole body and that of the kidneys and liver. The required constants having been determined* we find:

$$x_1 = \cdot0369x_2 + \cdot3178x_3 + \cdot0192x_4 + 2\cdot6715 \quad \ldots\ldots\ldots\ldots\ldots\ldots(1),$$

where x_1 is the weight of the heart in ounces, x_2 the body-weight in pounds, x_3 the weight of the kidneys in ounces, x_4 the weight of the liver in ounces.

The standard deviation of the prediction is 1·235 ozs., giving a mean error of ·96 oz.

The value of such an equation depends upon the nature of the regression† which cannot be properly determined when the data are too few or too scattered to allow of grouping. A rough empirical test is to see how far the predicted value agrees with the known weight in a sample of the material. Blakeman applied this test in his series of brain weights. We took every third case in our selected series, determined the probable weight of the heart from the above equation and compared this with the recorded weight. The mean absolute error in the whole 26 was ·98 oz., which is in reasonable agreement with our expectation. We then asked ourselves whether the prediction could be improved.

In the Tables II and III we have recorded, within brackets and inverted commas, some constants of "Body Length." Inquiry has elicited the fact that the "body length" was not true height at all but the length from the crown of the head to the *end of the toes* and had been recorded for the purposes of the undertaker. Since this measurement will be greatly affected by the degree to which the toes are flexed when *rigor mortis* sets in it does not necessarily bear a constant proportion to the stature, as was readily seen on examination of a short series of cases upon which both measurements had been made. Consequently the mean and standard deviation of this measurement are of no interest; but, since we found it to be substantially correlated with other measurements, it seemed just possible that its inclusion in an equation would improve the prediction. We found:

$$x_1 = \cdot0356x_2 + \cdot3034x_3 + \cdot0166x_4 + \cdot0418x_5 + \cdot2518 \quad \ldots\ldots\ldots\ldots(2),$$

where x_1 = heart weight in ounces, x_2 = body-weight in pounds, x_3 = kidneys in ounces, x_4 = liver in ounces, x_5 = "body length" in inches.

Applying this equation to the 26 test cases as before, the mean error proved to be ·97 oz., i.e. there was no sensible improvement in the fit.

Lastly we considered the effect of only taking two variables, the body-weight and the weight of the kidneys. The equation was:

$$x_1 = \cdot0413x_2 + \cdot3449x_3 + 2\cdot9187 \quad \ldots\ldots\ldots\ldots\ldots\ldots(3),$$

* In determining the various regression constants six places of decimals were retained in the coefficients of total correlation, i.e. we did not use simply the values tabulated in this paper. The work was arranged on the plan introduced by Yule, but several of the constants were checked by re-calculation, using the minors of the fundamental determinant in the ordinary way.

† An analysis of the data in Table VI of Greenwood's "First Study" shows that in the case of "healthy" organs the regression of heart weight upon kidney weight was effectively linear. For that case, $N=413$, $r=\cdot4004$, $\eta=\cdot4174$, and $\frac{\sqrt{N}}{\cdot67449}\times\frac{1}{2}\sqrt{\eta^2-r^2}=1\cdot776$.

where x_1 is the weight of the heart in ounces, x_2 the weight of the body in pounds, x_3 the weight of the kidneys in ounces.

(3) applied to the 26 cases gave a mean error of 1 ounce.

We accordingly conclude that the weight of the heart may be predicted from that of the body and kidneys with an average error of some 8 per cent. of the mean weight of the heart, and that the introduction of the liver does not appreciably improve the accuracy of the result. This equation may be of use occasionally in the *post mortem* room; rough as it is, we do not think any better formula has been found by the anatomist.

We finally come to the results yielded by the whole of the data sent us which fell between the required limits of age.

The necessary constants are set out in Tables IV and V A and B and these should be compared with Tables II and III. It will be seen at once that,

TABLE IV.

Constants calculated from All new Data. Males (25—55).

Variable	Mean	Standard Deviation	Coefficient of Variation
Heart	12·15 ± ·18 ozs.	2·700	22·22
Body-weight	128·89 ± 1·64 lbs.	24·367	18·91
Kidneys	10·77 ± ·15 ozs.	2·267	21·05
Liver	57·11 ± ·81 „	11·890	20·82
Age	42·60 ± ·60 yrs.	8·844	20·76
Brain	49·10 ± ·30 ozs.	4·464	9·09

TABLE V A.

Total Correlations. All new Data. Males (25—55).

	Heart	Body-weight	Kidney	Liver	Brain	Age
Heart ...	1	·56 ± ·05	·53 ± ·05	·46 ± ·05	·09 ± ·07	·06 ± ·07
Body-weight...	·56 ± ·05	1	·40 ± ·06	·57 ± ·05	·24 ± ·07	− ·04 ± ·07
Kidney ...	·53 ± ·05	·40 ± ·06	1	·32 ± ·06	·10 ± ·07	·04 ± ·07
Liver ...	·46 ± ·05	·57 ± ·05	·32 ± ·06	1	·14 ± ·07	− ·11 ± ·07
Brain ...	·09 ± ·07	·24 ± ·07	·10 ± ·07	·14 ± ·07	1	− ·08 ± ·07
Age ...	·06 ± ·07	− ·04 ± ·07	·04 ± ·07	− ·11 ± ·07	− ·08 ± ·07	1

TABLE V B.

Partial Correlations.

Variables	Constants	Correlation
Heart and Body-weight	Kidneys	·45 ± ·05
Heart and Kidneys	Body-weight	·40 ± ·06
Kidneys and Body-weight	Heart	·15 ± ·07

excepting the variability of the heart, no appreciable alteration can be discerned. Such changes as there are, e.g. the increased variability of the heart and its lessened correlation with the other organs, point to the first selection as being somewhat more healthy than the whole series, but the differences are evanescent. The regression equation of heart upon body and kidney weight as determined from the whole series is:

$$x_1 = \cdot 0462x_2 + \cdot 4260x_3 + 1\cdot 6143 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4),$$

where x_1 = heart weight in ounces, x = body-weight in pounds, x_3 = kidney weight in ounces.

The mean error for the 26 test cases is 1·1 ounces.

We think the inference to be drawn from this comparison is that, in order to arrive at the values of the true *post mortem* constants descriptive of a healthy "General Hospital Population," the process of selection need not be very stringent, so far as the diagnosed cause of death is concerned.

We also think the whole tendency of the present investigation is to suggest that the constants here published are, within the limits indicated by the errors of sampling, representative of a healthy "General Hospital Population." None of our results are in flagrant opposition either to the findings of observers equipped with more accurate data or to those previously obtained from hospital series. We hope, therefore, to have added another item of use to the student of a "General Hospital Population." Of course, being restricted to a single type of measurement, this study is of but limited interest. Shrubsall has published* the results of an inquiry into certain anthropological characters of a "General Hospital Population," while Greenwood and Candy† have shown cause for believing that the fatality of certain common diseases, such as lobar pneumonia, may be quite different in this class from that obtaining in the community at large. These are other items in a catalogue which has yet to be completed. It may well be possible for a future synthesist to paint a fairly accurate composite picture of a section of our countrymen which is of immense importance not only in itself but also as the substratum of medical instruction. At present, however, we must be contented with the task of collecting material, in particular statistical records.

The general conclusions of this inquiry may be summarised as follows:

(1) The mean weight of the heart in healthy adult males of the class from which patients in a London General Hospital are drawn is not far short of 12 ounces.

(2) The correlation between the weight of the heart and that of the whole body is not much less than ·5.

* F. C. Shrubsall, *Brit. Med. Journ.* Vol. II. p. 1689, 1904; *St Barts. Hosp. Reports*, Vol. XXXIX. p. 64.

† *Journ. Roy. Statist. Soc.* Vol. LXXIV. p. 365, 1911.

(3) The weight of the heart can be deduced from the weight of the body and that of the kidneys by means of a linear equation with an average error of about eight per cent.

(4) The weight of the body and that of the kidneys ought always to be considered before deciding whether a given heart is abnormally large or small.

(5) It is doubtful whether the weight of the heart is sensibly correlated with age in an adult population (of ages 25—55).

(6) The weight of the brain is less closely associated with the body weight and that of other viscera than is the heart weight.

APPENDIX OF MEASUREMENTS.

Data for the Study of Visceral and Organic Correlations in Healthy Male Adults (25—55).

Case Number	Age (years)	Body-weight (lbs.)	["Body-length" (ins.)]	Heart-weight (ozs.)	Brain-weight (ozs.)	Kidneys (ozs)	Liver (ozs.)	Cause of death
42, '12	45	140	69	11·5	51·5	5·25	57·5	Fract. Skull
68, '12	45	155	67	14·75	52·5	14·5	70	" "
80, '12	38	138	69	13·5	52	9	42·5	Abdom. Injury
114, '12	41	117	67	10·5	49	9·5	50·5	Fract. Pelvis
178, '12	48	132	67	14·75	50	12·5	57·5	Tetanus
190, '12	50	136	68	13·5	46	11·5	64	Ruptured Intestine
253, '12	52	126	68·5	10·5	52·5	10·75	47	Fract. Skull
20, '11	43	112	68	9·5	52·5	11·25	68·5	Bronch. Pneumonia
23, '11	34	157	71	11·5	49·5	9·5	74·5	Appendicectomy [mothorax
37, '11	45	128	67	12	48	11·5	74	Traum. Rup. of Oesoph. Pneu-
61, '11	25	95	67	10·5	49·5	10	48	Periton. Perf. Duoden. Ulcer
133, '11	41	133	69	11·75	47·75	12·75	65·5	Strang. Hernia Perit.
144, '11	34	106	66	10	—	9·5	57	Perf. Gastric Ulcer
169, '11	54	138	70	14·5	—	13·5	90	Fract. Spine
174, '11	53	145	67	12	—	9	48	Appendicectomy
281, '11	30	160	73	11	54·5	9	52·5	Accident
292, '11	31	116	76	14	—	14·5	71·5	Glioma of Brain
374, '11	38	148	72	15	39·5	16·5	68	Anaesthetic Death
554, '11	54	136	67·5	12·25	47	9·75	64	Accident
629, '11	35	119	70·5	11	50	8	63	Tetanus
913, '11	46	128	72	12	54	9	59	Fract. Skull
1197, '11	54	100	66	9·75	43	8·5	34	Fract. Pelvis
1234, '11	50	115	69	11·75	39·75	9·5	49·5	" "
1236, '11	49	121	68·5	13	50·25	11	56·5	Injury to Head
56, '10	52	149	72	14·25	52	10·25	70	Fract. Base
96, '10	34	168	72	13·25	47	9	75·5	Fract. Ribs
99, '10	26	95	66	9	43	7	50	Corrosive Poison
221, '10	49	126	67·5	12·75	46·5	11	66·5	Fract. Base
251, '10	47	108	69	9·5	51·5	9	55·5	Fract. Ribs
284, '10	36	188	71	13·5	48·5	11·5	79·5	Fract. Base
308, '10	40	98	68	10	43	10·5	48·5	Tetanus
403, '10	35	123	69	13	53	12·5	62	Fract. Skull
501, '10	46	102	64	12	46·5	14·25	34	Fract. Pelvis
522, '10	46	121	69	10·5	53	8·5	46	Epilepsy
608, '10	33	170	70·5	13·5	45	12	60	Fract. Skull
672, '10	52	129	71	11·5	53·5	11	54·5	Fract. Base

Data for the Study of Visceral Correlations—(continued).

Case Number	Age (years)	Body-weight (lbs.)	["Body-length" (ins.)]	Heart-weight (ozs.)	Brain-weight (ozs.)	Kidneys (ozs.)	Liver (ozs.)	Cause of Death
1047, '10	40	114	69	9·5	48	11·75	70·25	Fract. Skull
1048, '10	46	132	67·5	13	42·25	11·75	57·5	Fract. Base
1054, '10	51	156	67	15·5	49·5	12·5	70	Fract. Ribs
1159, '10	46	184	73	12·5	59	12·5	60	Shot
1160, '10	32	217	76	19·5	59	13·25	74·5	"
1172, '10	50	177	70	11·5	48	12·75	56·5	Fract. Ribs
1190, '10	49	112	66	9	44	9·5	46·5	Accident
226, '09	33	128	—	11·5	44·5	10·75	41	Fract. Base
294, '09	52	112	71	9·25	53	11	45	Fall
297, '09	45	114	69	9·75	48·5	9·5	42	Accident
298, '09	50	133	67	9·5	49	7	47	"
299, '09	50	127	71	14·25	47	13	66	"
329, '09	52	105	70	11·75	53	9	40	Oxalic Acid Poison
336, '09	29	121	69	10·75	54·5	12	55·5	Epileptic Fit
356, '09	48	108	69	11·5	49	9·5	50·5	Burns
365, '09	30	115	70	11·5	49	14	60	Tetanus
383, '09	26	135	73	14·5	44	9·75	53·5	Stabbed
449, '09	33	136	74·5	14·25	47·5	11	59	Tetanus
460, '09	43	122	72	11·5	50	11·25	64	Tetanus and Bronch. Pneumonia
865, '09	49	105	69	10·25	43	8	36	Cut Throat
1079, '09	48	127	66	13·5	56	11·5	53·5	Run Over
1261, '09	40	149	69	13	48·5	11	62·5	Accident
109, '08	26	105	65	10·5	46	10·5	62·5	Epileptic Fit [Peritonitis
145, '08	37	145	70	11·5	47	12	78	Anaesthetic Death, Appendic.
151, '08	43	96	65	9·5	47	8	43	Epileptic Fits
169, '08	35	105	64	12	44	8	50	Fract. Skull
172, '08	41	126	70	14·5	48	11·5	60	" "
186, '08	25	130	70	11·5	52·5	12	60	" "
202, '08	34	108	66	9	48	6·5	42	Scalds
207, '08	41	107	68	11	62·5	10	52	Fract. Skull
218, '08	44	147	68	10	51·5	9·75	63	Periton. Rup. Duod. Ulcer
221, '08	49	161	68·5	14·75	45·5	13·75	60	Fract. Base
384, '08	45	144	66	13·5	46	11	69	Burns
404, '08	32	136	65	12	52	13	—	Caught in Machinery
472, '08	26	148	73	11	55·5	10	57·5	Accident
505, '08	35	146	70	13	58·5	10	60	Opium Poisoning
542, '08	26	107	67	10·5	45	8·5	44·5	Fract. Skull
573, '08	35	169	71	14	—	14	73	Pulm. Emb. after Operation
680, '08	46	118	67	11	43	8·5	44	Fract. Spine
709, '08	26	122	67	10·5	55	12	49·5	Perf. Duod. Ulcer
751, '08	50	110	65	12	53·5	10	53	Tetanus
1014, '08	50	109	70·5	11·25	46	9	51·5	Fract. Spine
1104, '08	32	116	70	11	55	12·5	58·5	Stovain Poison

Classification of Causes of Death in above Data.

Accidents, Suicide and Homicide	49*
Intestinal Injuries and Post-Operative Effects	13
Tetanus	7
Poisoning	4
Epilepsy	4
Glioma of Brain	1
Bronch. Pneumonia	1
	79

* Fract. Skull 19. Other Fractures 11. "Accidents" 11. Homicide 4. Injury to Head 1. Burns and Scalds 3.

Other cases within the same limits of Age but excluded from the first Analysis.

Case Number	Age (years)	Body-weight (lbs.)	["Body-length" (ins.)]	Heart-weight (ozs.)	Brain-weight (ozs.)	Kidneys (ozs.)	Liver (ozs.)	Cause of Death
97, '09	50	166	74	12·75	48	14·25	92	Ruptured Aneurism
1244, '09	52	123	71·5	13	55	11	62·5	Ruptd. Gast. Art., Chr. Gast. Ulcers
1276, '09	28	108	71	8·5	48	9	45	Ruptd. Cong. Aneur. of Cereb. Artery
859, '09	54	128	74	13	—	9	56	Anaemia and Scars of Gast. Ulcers
810, '10	55	154	65	15*	48	13	59·5	Fract. Base (? Hyperpiesis)
15, '11	55	107	69	10·5	48	15·5	45·5	Operation. Cirrhosis of Liver
16, '11	53	191	72	12†	51	11·75	63	Operation. Enterectomy. Peritonitis
534, '11	52	102	65	11·75‡	45	8	43	Fits. Anaemia
73, '11	53	93	66	10	—	8·5	45	Carcinoma of Oesophagus
99, '11	45	174	71·5	28§	—	19·5	56·5	Heart Failure ; Hyperpiesis
104, '11	53	105	71	10·25	54·5	10	41·5	Rupt. of Cereb. Aneurism
136, '11	41	104	69	10	—	10·25	55	B. Pna. Cerebral Tumour
600, '08	52	105	68	8	39·5	7	45	Rupt. of Aneurism
345, '11	46	137	69	17·5‖	47	11·5	60	Accident
42, '11	50	80	70	9·5	—	9	50	Carcinoma of Stomach
19, '11	43	129	72	21·5	—	8·75	94	Chron. Nephritis
30, '11	50	103	70·5	9·5	48	14·5	43	Diss. Tuberculosis
1204, '11	46	128	69	14¶	45·5	11	47·5	Cerebral Haemorrhage
1245, '11	53	126	72	13	—	12	52	Rupt. of Aortic Aneurism
651, '11	40	135	69·5	12·5	49	8·75	57·5	? Hydrocyanic Poison ; ? Epilepsy
77, '12	27	129	69·5	10·25	48	9·25	64	Fract. Base

* Slight Hypertrophy. † Brown Atrophy. ‡ Fatty Degeneration. § Hyperpiesis.
‖ ? Hyperpiesis. ¶ Hyperpiesis.

THE MEASUREMENTS OF THE PELVIS, WITH SPECIAL REFERENCE TO OBSTETRIC PREDICTION.

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(1) *Introductory.*

The publication by Emmons* of a number of measurements of the female pelvis, carefully taken by himself, has afforded us an opportunity of investigating, by modern statistical methods, the relationship of the diameters to one another and to the bone measurements. As far as we can ascertain this has not previously been attempted. The subject has interested us not only from the statistical and anthropological sides but especially on account of its importance in practical obstetrics. Some of the diameters of the female pelvis can easily be measured on the living subject, others not at all, or only with great inconvenience to the patient. Unfortunately the two very important diameters at the pelvic brim, the obstetric conjugate and the transverse diameter, fall within the latter category. Empirical rules have been given, for example, to determine the obstetric conjugate from the diagonal conjugate, a diameter comparatively easily measured, but these lack both mathematical treatment and adequate statistical support. We have, in the following paper, considered methods of calculating these two important diameters from other pelvic measurements more readily obtainable. After making due allowance for moisture and soft parts we have left our results in a form which can be applied to the measurements as taken from the living subject.

* *Biometrika*, Vol. IX. p. 34, 1913.

Material. Emmons measured 217 pelves of the American Indian squaw in different museums in the United States of America. Our calculations have been made from these measurements; 216 pelves were considered in most cases, No. 115 in Emmons's Table being omitted as the diagonal conjugate was not stated. In calculations involving the pubic height only 212 were available, as this measurement was not given in Nos. 13, 72, 79, and 132 in his Table.

For the definitions of the different diameters and the way in which each was measured reference must be made to Emmons's paper. The names used by him have been retained with one exception. The term *oblique diameter*, as it has more than one significance, has been replaced by *diagonal conjugate*. The latter name is that usually given in this country to the diameter in question (sacro-subpubic) and is less likely to cause confusion.

Two modern English pelves, one male and one female, and two ancient Egyptian female pelves, kindly lent by Prof. Thane and Dr Derry respectively, were measured in the dry and moist state to ascertain differences in the diameters under these conditions. The measurements of these pelves and of an ancient Egyptian male pelvis, the property of Prof. Pearson, were employed to test the formulae calculated from the American Indian pelves.

For the numbers showing the thickness of the soft parts over the hip bone we are indebted to Dr Derry. They were obtained from measurements taken on 20 post mortem subjects. The maximum inter-cristal diameter was measured with callipers. As will appear later, a knowledge of the height of the hip bone may be of service in calculating diameters. This height, however, would vary in the living subject according to the position of the pelvis. If a woman be seated on a table it is easy to measure the maximum height of the iliac crest above the table. This could readily be done by the obstetrician if the measurement proved useful to him. It was therefore decided to consider this a measure of the height of the hip bone in the moist condition and covered with tissues. With the thigh of the corpse flexed to the sitting posture and the callipers pressed from above on to the iliac crest and from below on to the ischial tuberosity, this height is obtained. Dr Derry soon found, however, that he got the same result if he took the measurement with the subject supine, one limb of the callipers being pressed down from above on to the iliac crest as before, the instrument crossing in front of the groin, and the other limb passing between the thighs to reach the ischial tuberosity from below. Dr Braxton Hicks has confirmed this independently on three subjects. Accordingly most of the measurements have been taken in this manner.

The thickness of the soft parts was measured by means of an instrument with a rounded blade about as thick as a coarse darning needle but with not so fine a point. This was fitted into a hollow handle into which it could be pushed against a spring. A graduated scale showed the length of needle protruding from the handle. When in use the blade was passed through the skin and soft parts till its point was in contact with the bone. The handle was then pushed firmly

against the skin so that the only part of the blade protruding from it was that extending from the skin to the bone. The length of this was read off and gave the thickness of the soft parts covering the bone. This was measured over the ischial tuberosity, and over the iliac crest in vertical and horizontal directions. The first two measurements, subtracted from the measurement already obtained for the height of the hip bone covered with tissues, will give the height of that bone in the moist state. By subtracting the thickness of tissues over the ilium in a horizontal direction from the maximum inter-cristal diameter previously measured, the length of that diameter in the moist pelvis free from tissues can be ascertained.

The instrument was designed and made for us by Mr H. E. Soper of the Biometric Laboratory.

(2) *The relationship of the diameters and bone measurements to one another.*

The relationship of the diameters to one another was studied by means of the coefficient of correlation. As a preliminary, the average length and variability, as measured by the standard deviation, were found for each one. Emmons has already given the averages. Our results differ from his in some cases, probably owing to the fact that we divided the data into a larger number of groups. The diameters and bone measurements considered, together with the average and standard deviation of each, are shown in the following table. For the purpose of comparing the variabilities, the coefficients of variation are also given. All measurements in this and subsequent tables are expressed in centimetres.

TABLE I.

	Average	Standard Deviation	Coefficient of Variation
Inter-cristal	25·77 ± ·07	1·44 ± ·05	5·57 ± ·18
Inter-spinous	22·66 ± ·08	1·65 ± ·05	7·28 ± ·24
Transverse (brim)	12·97 ± ·03	·72 ± ·02	5·56 ± ·18
Diagonal conjugate ...	12·14 ± ·05	1·02 ± ·03	8·44 ± ·28
Obstetric conjugate ...	10·32 ± ·05	1·10 ± ·04	10·62 ± ·35
Antero-posterior (outlet) ...	11·61 ± ·04	·90 ± ·03	7·76 ± ·25
Inter-tuberal	9·78 ± ·04	·90 ± ·03	9·22 ± ·30
Posterior sagittal	7·56 ± ·04	·82 ± ·03	10·89 ± ·36
Pubic height	2·81 ± ·02	·52 ± ·02	18·30 ± ·62
Right hip—height	19·26 ± ·05	1·02 ± ·03	5·27 ± ·17
„ „ breadth ...	14·52 ± ·04	·87 ± ·03	5·97 ± ·19
Left hip—height	19·32 ± ·05	1·03 ± ·03	5·32 ± ·17
„ „ breadth	14·49 ± ·04	·83 ± ·03	5·72 ± ·19
Sacrum—height	10·00 ± ·05	1·15 ± ·04	11·52 ± ·38
„ breadth	11·47 ± ·03	·66 ± ·02	5·71 ± ·19

The pubic height is the most variable of all the measurements. Of the diameters the transverse and inter-cristal show the least variability. The height

and length of the hip bone and the breadth of the sacrum have coefficients not very different from those of the transverse and inter-cristal diameters, and the height of the sacrum has a variability just about double that of any other bone measurement. The results are not surprising. Apart from the variation in a measurement due to individual differences, there are other causes for variation in the case of these measurements taken on old pelves. It is not always easy to obtain accurate measurements, especially of the diameters, and after death parts of the bone get worn away. The wearing away of the pubic crest, for example, and the difficulty which may be experienced in determining the lowest point of the symphysis, must be accountable to a great extent for the large variability of the pubic height. The height of the sacrum, being dependent on the number of vertebrae united to form that bone and on the integrity of the tip, which is apt to get worn, is more variable than the breadth of that bone and than the height and breadth of the hip bone. The extremities of these last are rounded and less likely to be worn. The breadth is a little more variable than the height, and experience proves that, of the two, it is the more difficult to measure accurately.

The diameters must depend on the same factors as the bones, the individual differences, wear and tear, and difficulty of getting accurate measurements. The last especially must be of importance here. The obstetric conjugate, for example, depends upon the position of the sacral promontory, and therefore on the number of vertebrae forming the sacrum and on the proper fitting together of the bones, on the integrity of the upper and posterior part of the pubic bone, and on the ease or difficulty with which its anterior extremity can be determined. How much of the variation is due to each of these factors it is impossible to say. In such a diameter as the transverse there is little likelihood that the parts of the bone forming its extremities will be much worn away, but it would be unwise to go beyond a general statement of this kind.

The pubic height and the height of the sacrum vary more than any other measurement of a single bone with which we are acquainted. The measurements of the mandible come next in order. Their coefficients of variation, as given by C. D. Fawcett*, are, for the greatest height 9·93, for the greatest width at the condyles 7·46, and for the greatest width at the angles 7·62. The variations in the lengths of the long bones in different races (found for the French and Aino by Lee and Pearson†, for the Naqada by Warren‡, and for other races by Pearson§) have been compared with those of our measurements. The coefficients have as their limits 4·17 and 7·00, most of them being less than 5·5; hence the measurements of the pelvic bones, other than the pubic height and the height of the sacrum already considered, although in some few cases varying to about the same extent as the lengths of the long bones, have, on the whole, a tendency to be more variable.

* *Biometrika*, Vol. I. p. 408, 1902.

† *Proc. Roy. Soc.* LXI. p. 343, 1897.

‡ *Phil. Trans. Roy. Soc.* Series B. CLXXXIX. p. 135, 1897.

§ *The Chances of Death*, Vol. I. p. 256. London, 1897.

The coefficients of variation of the diameters were compared with those of the other recorded measurements which include more than one bone. The coefficients of the greater number of the skull measurements* lie between 3 and 5. There are a few which are more nearly equal to those in Table I. Some of the measurements of the face, for example, have coefficients lying between 6 and 8, and that of the breadth of the palate is 9·29. The diameters of the pelvis are, however, more variable than the bulk of the cranial measurements.

The average bone measurements given in Table I are also of interest. The asymmetry of the female pelvis has been pointed out from time to time by anatomists and has been strongly insisted upon by Hasse†. According to him the height of the left side of the pelvis is greater than that of the right, while the breadth is less. The numbers in the table bear out this statement, but, while Hasse makes these differences about 1 cm. each, the table shows them to be ·06 and ·03 cm. respectively. In this connection it may be noted that, in the 20 subjects measured by Dr Derry, the average height of the left hip bone in the moist condition was ·15 cm. greater than that of the right. Of the three dry female pelves used by us for testing purposes one followed Hasse's rule but the others varied, so that the average of the three showed the height of the right hip bone to be ·05 and its breadth ·04 cm. greater than that of the left. The number of negative results, though worthy of record, is, however, too small to place against the positive findings.

The coefficients of correlation were next found for every diameter taken with every other diameter in turn. The results are summarised in the table.

TABLE II.

	Inter-crests	Inter-spines	Trans-verse	Diagonal conjugate	Obstetric conjugate	Antero-posterior	Inter-tubers	Post-sagittal	Pubic height
Inter-crests	1	·79 ± ·02	·61 ± ·03	·24 ± ·04	·17 ± ·04	·30 ± ·04	·10 ± ·05	·11 ± ·05	·28 ± ·04
Inter-spines	·79 ± ·02	1	·52 ± ·03	·16 ± ·04	·13 ± ·05	·18 ± ·04	·07 ± ·05	·13 ± ·05	·22 ± ·04
Transverse	·61 ± ·03	·52 ± ·03	1	·09 ± ·05	·07 ± ·05	·35 ± ·04	·32 ± ·04	·17 ± ·04	·10 ± ·05
Diagonal conjugate ...	·24 ± ·04	·16 ± ·04	·09 ± ·05	1	·91 ± ·01	·31 ± ·04	·20 ± ·04	·21 ± ·04	·14 ± ·05
Obstetric conjugate ...	·17 ± ·04	·13 ± ·05	·07 ± ·05	·91 ± ·01	1	·30 ± ·04	·19 ± ·04	·21 ± ·04	·05 ± ·05
Antero-posterior ...	·30 ± ·04	·18 ± ·04	·35 ± ·04	·31 ± ·04	·30 ± ·04	1	·32 ± ·04	·49 ± ·03	·07 ± ·05
Inter-tubers ...	·10 ± ·05	·07 ± ·05	·32 ± ·04	·20 ± ·04	·19 ± ·04	·32 ± ·04	1	·36 ± ·04	− ·06 ± ·05
Post-sagittal	·11 ± ·05	·13 ± ·05	·17 ± ·04	·21 ± ·04	·21 ± ·04	·49 ± ·03	·36 ± ·04	1	·004 ± ·05
Pubic height ...	·28 ± ·04	·22 ± ·04	·10 ± ·05	·14 ± ·05	·05 ± ·05	·07 ± ·05	− ·06 ± ·05	·004 ± ·05	1

* Fawcett, C. D., *loc. cit.*

† *Archiv für Anat.* p. 244, 1891. *Ibid.* p. 1, 1910.

As the obstetric conjugate and the transverse diameter at the brim have to be obtained in practice not by direct measurement but by calculation, and as a knowledge of them is important and often necessary, special attention should be paid to these two diameters. The highest correlation (·91) exists between the obstetric and diagonal conjugates, and this justifies the reliance always placed by the obstetrician on the use of the latter to determine the former. The obstetric conjugate shows a moderate degree of correlation (·30) with the antero-posterior diameter at the outlet, but the coefficient is small between it and each of the other diameters, being very low for the transverse diameter (·07) and pubic height (·05). The diameters with which the transverse diameter at the brim is most highly correlated are the inter-cristal (·61) and inter-spinous (·52). Next in order are the antero-posterior at the outlet (·35) and the inter-tuberal (·32). With the other diameters the correlation is low.

In view of the fact that the pubic height forms one side of a triangle, of which the obstetric and diagonal conjugates form the other two sides, it is sometimes taken into consideration in calculating the obstetric conjugate from the diagonal conjugate. Thus, according to Waldeyer*, "in order to obtain the obstetric conjugate from the diagonal conjugate 1·75 to 2 cm., on an average, must be subtracted, and, the more acute the angle between the diagonal conjugate and the symphysis, and the higher the symphysis, the more must be taken away." It will be seen, on referring to the table, that the pubic height is not highly correlated with any diameter, and that with the obstetric and diagonal conjugates the coefficients are ·05 and ·14 respectively.

In order to arrive at formulae for finding the diameters it is necessary to use the measurements with which they are most closely correlated. The coefficients of correlation of the obstetric conjugate and the transverse diameter at the brim with the bone measurements were therefore found, to see whether any of them would be high enough to be of service. These are now given :

		Obstetric conjugate	Transverse
Right hip—height	...	·55 ± ·03	·48 ± ·04
„ „ breadth	...	·48 ± ·04	·45 ± ·04
Left hip—height	...	·56 ± ·03	·45 ± ·04
„ „ breadth	...	·51 ± ·03	·48 ± ·04
Sacrum—height	...	·31 ± ·04	·21 ± ·04
„ breadth	...	·37 ± ·04	·56 ± ·03

All these measurements are more highly correlated with the obstetric conjugate than is any diameter except the diagonal conjugate (·91). With the transverse diameter the measurements of the hip bone show higher correlation than do any diameters except the inter-cristal (·61) and inter-spinous (·52), and the coefficient of correlation of the breadth of the sacrum with this diameter (·56) is exceeded only by that of the inter-cristal with it. Of these measurements, however, the only one which can easily be made with sufficient accuracy on the living subject

* *Das Becken*, p. 49. Bonn, 1899.

is the height of the hip bone. This can be taken in the sitting posture as already indicated. Since it is one of the measurements most highly correlated with both the diameters under consideration, it will have to be taken into account in working out the formulae from which these diameters are to be found. Its coefficients of correlation with the diameters most closely correlated with the obstetric conjugate (diagonal conjugate) and the transverse diameter (inter-cristal and inter-spinous) will therefore be required. These have been calculated for both hip bones.

	Right hip—height	Left hip—height
Diagonal conjugate	·63 ± ·03	·64 ± ·03
Inter-crests	·56 ± ·03	·57 ± ·03
Inter-spines	·44 ± ·04	·46 ± ·04

Apart from the closeness of the figures on the two sides these results call for no particular notice.

As a matter of anthropological interest the relationship of the bone measurements to one another was studied, and a table of the coefficients of correlation drawn up on a plan similar to that employed for the diameters. The correlation is greater between corresponding measurements of the hip bones on the two sides than between the height and length of the same bone. Thus the heights of the two hip bones have a coefficient ·98 and the breadths a coefficient ·94, while that for the height and breadth of the right hip bone is ·78 and for the same measurements on the left side ·81. This closer relationship between corresponding measurements on the two sides than between measurements on the same side has been noted by previous observers for other bones*. The crossed correlation between the height of one bone and the breadth of the other is not very different from the direct correlation between the height and breadth of the same bone, e.g. height of right hip bone with breadth of left bone gives a coefficient ·79, height of right bone with breadth of right bone a coefficient ·78, height of left

TABLE III.

	Right hip—height	Right hip—breadth	Left hip—height	Left hip—breadth	Sacrum—height	Sacrum—breadth
Right hip—height ...	1	·78 ± ·02	·98 ± ·002	·79 ± ·02	·34 ± ·04	·59 ± ·03
Right hip—breadth ...	·78 ± ·02	1	·77 ± ·02	·94 ± ·005	·31 ± ·04	·55 ± ·03
Left hip—height ...	·98 ± ·002	·77 ± ·02	1	·81 ± ·02	·37 ± ·04	·61 ± ·03
Left hip—breadth ...	·79 ± ·02	·94 ± ·005	·81 ± ·02	1	·30 ± ·04	·58 ± ·03
Sacrum—height ...	·34 ± ·04	·31 ± ·04	·37 ± ·04	·30 ± ·04	1	·32 ± ·04
Sacrum—breadth ...	·59 ± ·03	·55 ± ·03	·61 ± ·03	·58 ± ·03	·32 ± ·04	1

* Lewenz and Whiteley, *Biometrika*, Vol. I. p. 345, 1902.

bone with breadth of right bone a coefficient ·77, and height of left bone with breadth of left bone a coefficient ·81. Note also that there is no great difference between the coefficients of the corresponding measurements of the right and left hip bones with the sacrum (see first four numbers in the last row or column in the table).

Of only one pelvic bone, the sacrum, have the coefficients of correlation of the measurements been recorded previously. Warren*, studying the bones of the Naqada race, found that the coefficient of correlation for the height and breadth of this bone was ·46 for 32 males examined and ·31 for 45 females. The latter number is practically identical with our finding (·32). The coefficients given by him to show the correlation of the measurements of the long bones with one another lie between ·82 and ·98 for the male, and ·70 and ·96 for the female, with the exception of that for the maximum length of the clavicle with the oblique length of the humerus, which is ·68 for the male and ·53 for the female. Lewenz and Whiteley†, for the bones of the hand, found coefficients with a range ·43 to ·90 for measurements of the same finger, and ·59 to ·95 for other measurements on the same hand. If we omit coefficients between corresponding measurements on the two sides our coefficients have a range ·30 to ·79, and, on the whole, are lower than those between the measurements of the long bones together and of the bones of the hand together, being nearer to the latter than to the former. They are, however, greater than those between the diameters of the skull which C. D. Fawcett‡ found to lie between ·27 and ·49 for the male and ·12 and ·28 for the female.

It is interesting to note here that the coefficient between the length and breadth of the skull is ·34 in the male and ·14 in the female, while that between the length and breadth of the pelvis at the brim, i.e. between the transverse diameter and the obstetric conjugate, is ·07, and at the outlet, i.e. between the antero-posterior and inter-tuberal diameters, ·32.

(3) *The finding of the obstetric conjugate and the transverse diameter for the d-y pelvis.*

The method adopted to determine the non-measurable from the measurable diameters was that employed by Prof. Pearson§ for obtaining the stature of an individual from the lengths of the long bones. The equation of the regression line was used for this purpose. In the equations which follow the lengths of the diameters are represented by letters as shown below:

Obstetric conjugate	C	Inter-tubers	I
Transverse	T	Inter-crests	K
Diagonal conjugate	D	Inter-spines	S
Antero-posterior	A	Pubic height	P

Height of right hip R
„ „ left „ L

* *loc. cit.* † *loc. cit.* ‡ *loc. cit.*
§ *Phil. Trans. Roy. Soc.* Series A. Vol. CXCII. p. 169, 1898.

(A) *Obstetric conjugate.* Equations were obtained for deriving this from each of the diameters with which it is most closely correlated, viz. the diagonal conjugate (·91), and the antero-posterior (·30). These equations are

$$C = \cdot 978D - 1\cdot 553 \pm \cdot 299 \quad \ldots\ldots\ldots\ldots\ldots\ldots (a),$$

$$C = \cdot 365A + 6\cdot 081 \pm \cdot 705 \quad \ldots\ldots\ldots\ldots\ldots\ldots (b),$$

the first of which has a much smaller probable error (·299) than the second (·705). A single equation was also obtained, using both diameters

$$C = \cdot 972D + \cdot 023A - 1\cdot 743 \pm \cdot 298 \quad \ldots\ldots\ldots\ldots\ldots\ldots (c)$$

with an extremely slight improvement of the probable error as compared with (*a*).

The diameters next in order of correlation with the obstetric conjugate are the posterior sagittal (·21) and the inter-tuberal (·19). The posterior sagittal is not measurable on the living subject. The inter-tuberal was measured in a special way on the dry pelvis by Emmons and is not necessarily the same as the inter-tuberal diameter as understood by the obstetrician. The method is not applicable to the living subject, but this diameter was employed here to test whether it was of sufficient importance for its measurement to be followed up further. An equation was formed by taking it with the diagonal conjugate and the antero-posterior diameter

$$C = \cdot 972D + \cdot 023A + \cdot 001I - 1\cdot 745 \pm \cdot 299 \quad \ldots\ldots\ldots\ldots\ldots\ldots (d).$$

On comparing (*c*) with (*d*) it is apparent that the addition of the inter-tuberal diameter makes little difference, and that little to the bad, as is shown by the probable errors. This diameter will therefore not be considered further.

It has been pointed out previously that the pubic height is sometimes used in calculating the obstetric conjugate but that its correlation with this diameter is low (·05). The equation connecting the obstetric conjugate with the pubic height is

$$C = \cdot 110P + 10\cdot 011 \pm \cdot 738 \quad \ldots\ldots\ldots\ldots\ldots\ldots (e),$$

having the largest probable error (·738) of the equations yet obtained. The result of combining the pubic height with the diagonal conjugate is, however, good:

$$C = \cdot 989D - \cdot 165P - 1\cdot 229 \pm \cdot 293 \quad \ldots\ldots\ldots\ldots\ldots\ldots (f)$$

with a probable error lower than that of (*c*). This is due to the fact that, although the obstetric conjugate is more highly correlated with the antero-posterior diameter (·30) than with the pubic height (·05), the former of these two is more highly correlated with the diagonal conjugate (·31) than is the latter (·14), and it has been found that when the crossed correlation between the variables is high the resulting equation is not so good as when the crossed correlation is low. The pubic height, whether measured externally or internally, involves exposure of or inconvenience to the patient, so that it is desirable to avoid its use if just as good or nearly as good results can be obtained by other means.

Of the measurements which can be taken on the living subject, next to the diagonal conjugate the height of the hip bone shows the closest correlation with the obstetric conjugate (right ·55, left ·56). Equations were formed using the height of each hip bone

$$C = \cdot 590R - 1\cdot 037 \pm \cdot 619 \quad \ldots\ldots\ldots\ldots\ldots\ldots (g),$$

$$C = \cdot 602L - 1\cdot 310 \pm \cdot 610 \quad \ldots\ldots\ldots\ldots\ldots\ldots (h).$$

The equations as tested by probable errors are better than (*b*) and (*e*) but not as good as (*a*), (*c*), (*d*), and (*f*), but if each of the measurements be taken with the diagonal conjugate the resulting equations are exceedingly good

$$C = 1\cdot 008D - \cdot 049R - \cdot 977 \pm \cdot 298 \ldots\ldots\ldots\ldots\ldots\ldots (i),$$

$$C = 1\cdot 005D - \cdot 042L - 1\cdot 075 \pm \cdot 298 \quad \ldots\ldots\ldots\ldots\ldots\ldots (j).$$

The probable errors to four places would be ·2976 and ·2978 respectively while that of (*c*) is ·2984, so that the probable errors are less than that of any equation except (*f*). These equations have a practical advantage over (*f*), for the height of the hip bone can be easily measured on the living subject whilst, as already mentioned, there are disadvantages attached to the measurement of the pubic height. Moreover, the measurement of the height of the hip bone is less objectionable to the patient than that of the antero-posterior diameter, so that equations (*i*) and (*j*) possess a practical advantage over (*c*).

To facilitate reference all the equations for finding the obstetric conjugate are now collected together:

(*a*) $C = \cdot 978D - 1\cdot 553 \pm \cdot 299.$

(*b*) $C = \cdot 365A + 6\cdot 081 \pm \cdot 705.$

(*c*) $C = \cdot 972D + \cdot 023A - 1\cdot 743 \pm \cdot 298.$

(*d*) $C = \cdot 972D + \cdot 023A + \cdot 001I - 1\cdot 745 \pm \cdot 299.$

(*e*) $C = \cdot 110P + 10\cdot 011 \pm \cdot 738.$

(*f*) $C = \cdot 989D - \cdot 165P - 1\cdot 229 \pm \cdot 293.$

(*g*) $C = \cdot 590R - 1\cdot 037 \pm \cdot 619.$

(*h*) $C = \cdot 602L - 1\cdot 310 \pm \cdot 610.$

(*i*) $C = 1\cdot 008D - \cdot 049R - 977 \pm \cdot 298.$

(*j*) $C = 1\cdot 005D - \cdot 042L - 1\cdot 075 \pm \cdot 298.$

Equations (*f*), (*i*) and (*j*) appear to indicate that, for a constant diagonal conjugate, the obstetric conjugate is smaller the higher the pelvic wall.

These formulae have been tested for the original series and for five other pelves. The cards of 25 of the 216 pelves were picked out at random and the obstetric conjugate was calculated from the recorded measurements by means of the equations, with satisfactory results. The square root of the mean square deviation of the calculated from the recorded values of the obstetric conjugate was multiplied by ·67449 and compared with the probable errors of the equations. The values calculated from equations (*b*), (*g*), and (*h*) fell within this probable

error. The others exceeded it, but the greatest difference was only ·08, i.e., since we are working in centimetres, less than 1 millimetre.

The formulae were also tested for five pelves measured by us. Three of these were ancient Egyptian (I and II female, III male), and had to be fitted together to be measured, but the other two were modern English (IV female, V male), with the ligaments attached. The inter-tuberal diameter was not measured since it would have required the application of Emmons's method, and this we were not prepared to carry out as it had already been found that, in the determination of the obstetric conjugate and the transverse diameter, nothing was gained by the use of this diameter. Equation (*d*) was therefore not tested. The differences of the calculated from the recorded values for these pelves are given below for each equation.

TABLE IV.

Pelvis Number...	I	II	III	IV	V
Equation (*a*) ...	1·33	·39	− ·28	·15	− ·54
„ (*b*) ...	·83	− ·76	·52	2·65	·33
„ (*c*) ...	1·35	·40	− ·26	·19	− ·52
„ (*e*) ...	·44	−1·09	·07	2·00	− ·15
„ (*f*) ...	1·26	·59	− ·01	·28	− ·32
„ (*g*) ...	1·49	− ·21	— ·51	2·24	−1·35
„ (*h*) ...	1·43	− ·10	− ·53	2·42	−1·43
„ (*i*) ...	1·27	·37	− ·23	·07	− ·45
„ (*j*) ...	1·29	·37	− ·23	·08	− ·46

Perhaps the most interesting of these numbers are those for the modern English female pelvis IV. Here the results for the equations formed from the diagonal conjugate and the height of the hip bone, (*i*) and (*j*), are excellent, the differences between recorded and calculated values being only ·07 and ·08 cm. The equations formed from the diagonal conjugate singly (*a*), and the diagonal conjugate and antero-posterior diameter (*c*), are the next best, the differences being ·15 and ·19 cm. respectively, then that from the diagonal conjugate and pubic height (*f*), with a difference ·28 cm. All the others have differences 2 cm. or more.

The figures bring out strongly what our previous discussion on the probable errors has shown, namely that, excluding, for reasons considered, the equations formed with the pubic height, the best equations are those containing the diagonal conjugate singly or combined with the height of the hip bone or the antero-posterior diameter.

The equations (*i*), (*j*), (*a*), (*c*) and (*f*) give differences less than a centimetre in four of the five pelves. No other equation does this except (*b*), but the difference for this in the remaining pelvis, which happens to be the modern English female pelvis IV, is 2·65 cm., so that the equations which give the best results on the whole are those which give the best results with pelvis IV. It

should be noted that all the equations give fairly good values for the male Egyptian pelvis III and most of them for the male English pelvis V.

The best of the formulae obtained from the measurements of the American Indian female pelvis for finding the obstetric conjugate are therefore applicable to the modern European female pelvis, and will give good results even for the male pelvis.

(B) *Transverse diameter* (*brim*). The inter-cristal (·61), inter-spinous (·52), and antero-posterior (·35), are the diameters most closely correlated with the transverse diameter. By taking them singly and combined, equations for finding this diameter were formed. Equations were also formed from the height of the hip bone taken singly or combined with the diameters. This bone measurement has proved serviceable in finding the obstetric conjugate and was used here, as its correlation with the transverse diameter also is fairly high (right ·48, left ·45). The following equations were obtained:

$$(k)\quad T = \cdot 305K + 5\cdot 096 \pm \cdot 386.$$

$$(l)\quad T = \cdot 228S + 7\cdot 791 \pm \cdot 415.$$

$$(m)\quad T = \cdot 284A + 9\cdot 673 \pm \cdot 455.$$

$$(n)\quad T = \cdot 261K + \cdot 049S + 4\cdot 864 \pm \cdot 385.$$

$$(o)\quad T = \cdot 221K + \cdot 061S + \cdot 160A + 4\cdot 044 \pm \cdot 374.$$

$$(p)\quad T = \cdot 341R + 6\cdot 398 \pm \cdot 427.$$

$$(q)\quad T = \cdot 320L + 6\cdot 794 \pm \cdot 433.$$

$$(r)\quad T = \cdot 248K + \cdot 144R + 3\cdot 799 \pm \cdot 378.$$

$$(s)\quad T = \cdot 259K + \cdot 115L + 4\cdot 078 \pm \cdot 381.$$

$$(t)\quad T = \cdot 169S + \cdot 221R + 4\cdot 883 \pm \cdot 392.$$

$$(u)\quad T = \cdot 174S + \cdot 192L + 5\cdot 323 \pm \cdot 398.$$

$$(v)\quad T = \cdot 202K + \cdot 050S + \cdot 145R + 3\cdot 835 \pm \cdot 376.$$

$$(w)\quad T = \cdot 217K + \cdot 047S + \cdot 113L + 4\cdot 155 \pm \cdot 380.$$

Of the equations formed by taking the measurements singly, namely (*k*) from inter-cristal, (*l*) inter-spinous, (*m*) antero-posterior diameter, (*p*) height of right hip bone, (*q*) height of left hip bone, (*k*) has the lowest probable error, ·386. This is slightly improved (·385) by combining the inter-spinous with the inter-cristal diameter as at (*n*). The inter-cristal diameter combined with the height of the hip bone gives a still lower probable error (right ·378, left ·381), as is seen in equations (*r*) and (*s*), while (*t*) and (*u*) show that the inter-spinous diameter and the height of the hip bone together give a higher probable error even than the inter-cristal diameter alone (*k*). By combining three measurements, however, there is noticeable improvement. Equation (*v*) formed from the inter-cristal and inter-spinous diameters and the height of the right hip bone has a probable error ·376 which is slightly lower than that of (*r*), from the inter-cristal diameter and height of right hip bone (·378); and (*w*), from the inter-cristal and inter-spinous

diameters and the height of the left hip bone, shows similar improvement as compared with (*s*), from the inter-cristal diameter and height of left hip bone (·381 and ·380 respectively); while (*o*), from the inter-cristal, inter-spinous, and antero-posterior diameters, has the lowest probable error, ·374.

The best formula then for finding the transverse diameter from a single diameter is (*k*), from the inter-cristal diameter. For two measurements, (*r*) and (*s*), from the inter-cristal diameter with the height of the right and left hip bones respectively, are slightly better than (*n*), from the inter-cristal and inter-spinous diameters, and any of these can conveniently be used as all the measurements are easily taken. In the combination of the inter-cristal and inter-spinous diameters with a third measurement, the antero-posterior diameter gives a better equation (*o*) than the height of the hip bone, (*v*) and (*w*), but the measurement of the latter is less objectionable to the patient.

These formulae were tested in the same way as those for the obstetric conjugate. The transverse diameter was calculated from the recorded measurements of 25 of the 216 pelves, picked out at random. The square root of the mean square deviation of the calculated from the recorded values of the transverse diameter was multiplied by ·67449 and compared with the probable errors of the equations. In every case they fell within this probable error.

The formulae were also tested for the five pelves measured by us (I and II Egyptian female, III Egyptian male, IV English female, V English male). The differences of the calculated from the recorded values for these are given below for each equation.

TABLE V.

Pelvis Number...	I	II	III	IV	V
Equation (*k*) ...	− ·58	−1·04	−1·18	− ·27	−1·57
„ (*l*) ...	− ·99	− ·87	−1·58	+ ·17	−1·48
„ (*m*) ...	−1·30	−1·13	− ·21	+ ·31	−1·08
„ (*n*) ...	− ·33	− ·74	−1·06	+ ·08	−1·30
„ (*o*) ...	− ·51	− ·93	−1·16	+ ·09	−1·40
„ (*p*) ...	−1·00	− ·86	− ·86	− ·04	−2·12
„ (*q*) ...	−1·09	− ·83	− ·83	+ ·05	−2·10
„ (*r*) ...	− ·51	− ·90	−1·22	− ·20	−1·86
„ (*s*) ...	− ·54	− ·91	−1·22	− ·18	−1·81
„ (*t*) ...	− ·74	− ·77	−1·56	+ ·15	−1·95
„ (*u*) ...	− ·81	− ·77	−1·45	+ ·20	−1·90
„ (*v*) ...	− ·52	− ·87	−1·37	− ·12	−1·85
„ (*w*) ...	− ·59	− ·91	−1·38	− ·13	−1·83

Two things are at once obvious, (1) that the best result for every equation is given by the modern English female pelvis IV, (2) that the results for the two male pelves III and V are not very good. In the case of the equations (*o*), (*v*), (*w*), (*r*), (*s*), (*n*) and (*k*), shown to have the least probable errors, the differences for the three female pelves, I, II, and IV, are all less than a centimetre except that of (*k*) for pelvis II, which is a little more. The best results for the English

female pelvis IV are given by (p) and (q), but their results are amongst the worst for pelvis I. The table shows that the equations selected from a consideration of probable errors may be expected to give good results, that these formulae may be applied to the modern European female pelvis, and that they cannot be satisfactorily applied to the male pelvis.

(4) *The effects of moisture on the pelvic measurements.*

The formulae which we have obtained will give the obstetric conjugate and the transverse diameter for the dry pelvis. These will not necessarily be the same in the living subject for there the bones contain moisture and are covered by the soft tissues. For practical purposes it is required to know what effect these differences will have on the measurements.

The effect of moisture was studied by soaking a dry pelvis in water and comparing its measurements in the dry state with those taken after it had been in water for some time. This was done with two ancient Egyptian female pelves lent by Dr Derry. The bones of the pelves were measured, then fitted together and kept in position by strong elastic bands, and the diameters measured with callipers. The pelvis was then taken to pieces and the bones immersed in water. After an interval they were taken out, held up to drip, and excess of water removed from them with a cloth. They were measured, fitted together again, and the diameters measured. This was repeated at several intervals. Finally they were taken out of the water and left in the air to dry for some days, and the bones and diameters were again measured. The results were unsatisfactory, as the following example, giving the measurements at different intervals, will show.

TABLE VI.

Pelvis I	Dry	In water 2 hours	In water 4 hours	In water 7 hours	In water 70 hours	In water 97 hours	After drying for 14 days
Inter-crests	22·30	22·52	22·45	22·39	22·82	23·02*	22·79
Inter-spines	19·81	19·95	19·99	19·91	20·23	20·52	20·23
Transverse	11·33	11·30	11·23	11·25	11·24	11·34	11·14
Diagonal conjugate ...	11·18	11·30	11·30	11·23	11·13	11·28	10·96
Obstetric conjugate ...	10·71	10·70	10·70	10·69	?	?	?
Antero-posterior ...	10·42	10·25	10·52	10·28	10·51	10·35	10·31
Pubic height	2·32	2·30	2·45	2·47	?	?	?
Right hip—height ...	17·40	17·50	17·47	17·50	17·50	17·53*	17·42
„ „ breadth ...	14·29	14·20	14·15	14·17	14·16	14·15	14·03
Left hip—height ...	17·60	17·75	17·60	17·60	17·60	17·63*	17·50
„ „ breadth ...	14·02	13·85	13·85	13·88	13·83	13·85	13·60
Sacrum—height ...	8·72	8·88	8·80	8·86	8·87	8·87	8·70
„ breadth ...	10·30	10·16	10·17	10·13	10·13	10·14	10·07

Obviously the changes in the measurements are small and therefore not easy to detect where there are opportunities for error as in this case. The initial

* Both hip bones were cracked at the crest.

difficulty of putting the bones together on different occasions so as to get constant measurements is increased under the conditions of the experiment. After the bones have taken up water the shape of their articular surfaces is altered; hence the bones do not fit together in quite the same way as they did before, and the measurements are not fully comparable. A difference in the tilt of the sacrum, for example, may affect the two conjugates and the antero-posterior diameter.

But there is another difficulty. These old bones are very fragile and are apt to crack, as both hip bones did in this experiment. Flakes of bone come away from the surface. This happened at the upper part of the pubes in this pelvis, and is the reason why the record for the obstetric conjugate and pubic height is incomplete. Fortunately we were able to surmount these difficulties.

Prof. Thane lent us two modern English pelves, one female and one male (previously referred to as IV and V respectively), with the bones still attached to each other by the ligaments. Both were measured in the dry state. Pelvis IV was measured after immersion in water for 22 and 68 hours, and subsequent drying for 39 days. Pelvis V was measured after 98 hours in water, and subsequent drying for 35 days. The final measurements were very nearly the same as the initial, so that the mean of the two was taken as a good measure of the diameters in the dry pelvis. In the case of the first pelvis (IV) the numbers after 22 and 68 hours in water were also very close, and the mean of these was taken as the measurement in the moist state. The measurements in the dry state with their increase in the moist state are tabulated below.

The negative sign in the fourth column indicates that moisture caused some diminution of the measurement in question.

TABLE VII.

	Pelvis IV ♀		Pelvis V ♂		Mean of Differences
	Dry	Difference	Dry	Difference	
Inter-crests	26·26	·10	26·54	·18	·14
Inter-spines	21·40	·02	23·29	·04	·03
Transverse	15·85	·06	11·63	·08	·07
Diagonal conjugate ...	14·14	·15	12·70	·10	·13
Obstetric conjugate ...	12·42	·00	10·32	·02	·01
Antero-posterior ...	10·11	·13	10·71	·03	·08
Pubic height	3·72	·22	4·20	·21	·22
Right hip—height ...	19·03	·07	21·55	·05	·06
„ „ breadth ...	15·78	·06	15·87	– ·07	– ·01
Left hip—height ...	18·79	·11	21·70	·10	·11
„ „ breadth ...	15·77	·05	15·87	·03	·04

The differences are small, the greatest being a little over 2 mm. for the pubic height. Moreover they are very close for the two pelves. The means of these

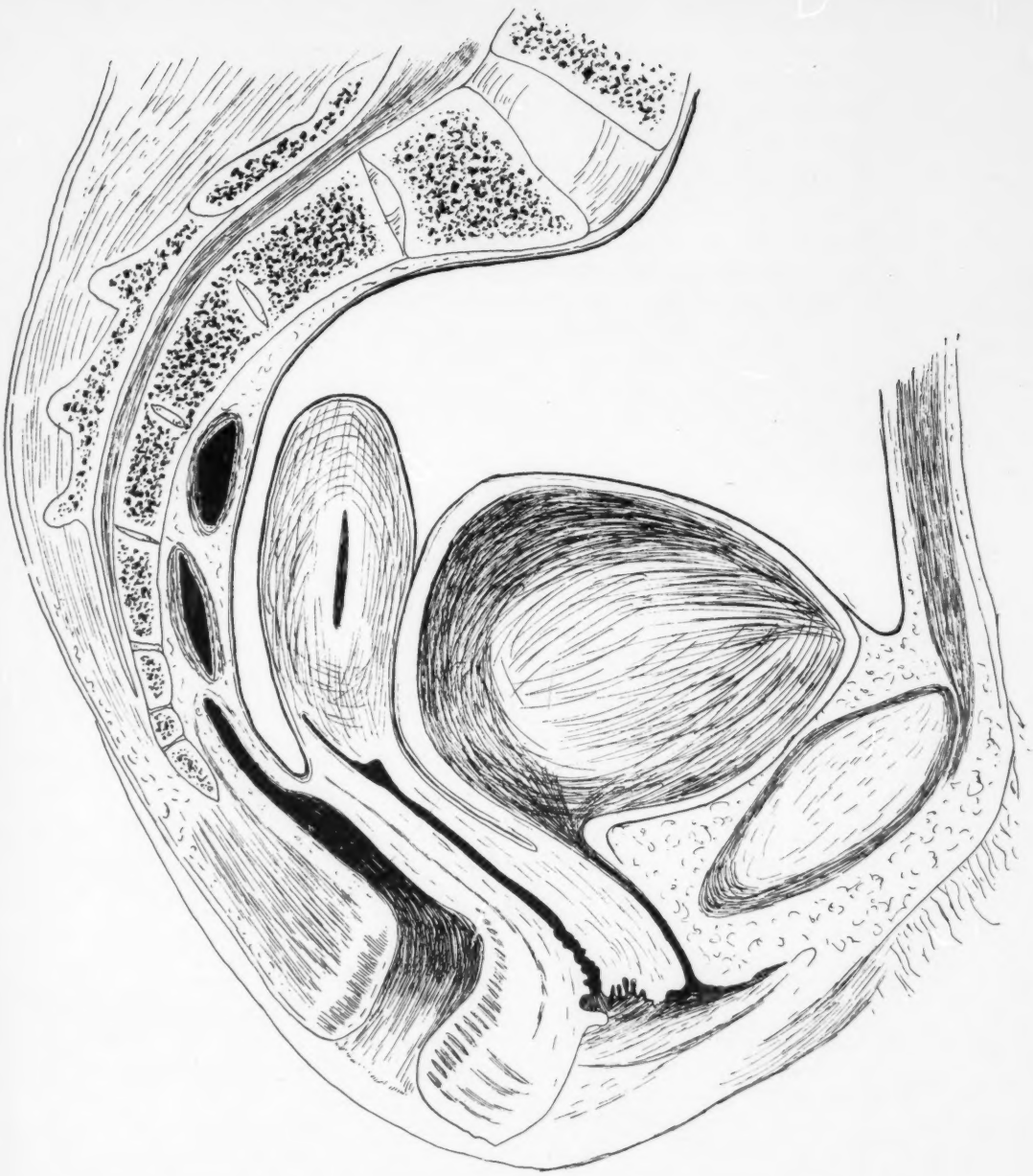
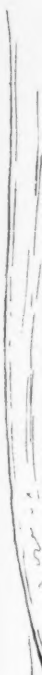


FIG. 1. Median section of the pelvis of a woman 35 years old. She was rather thin. From a drawing to scale by Professor Symington.



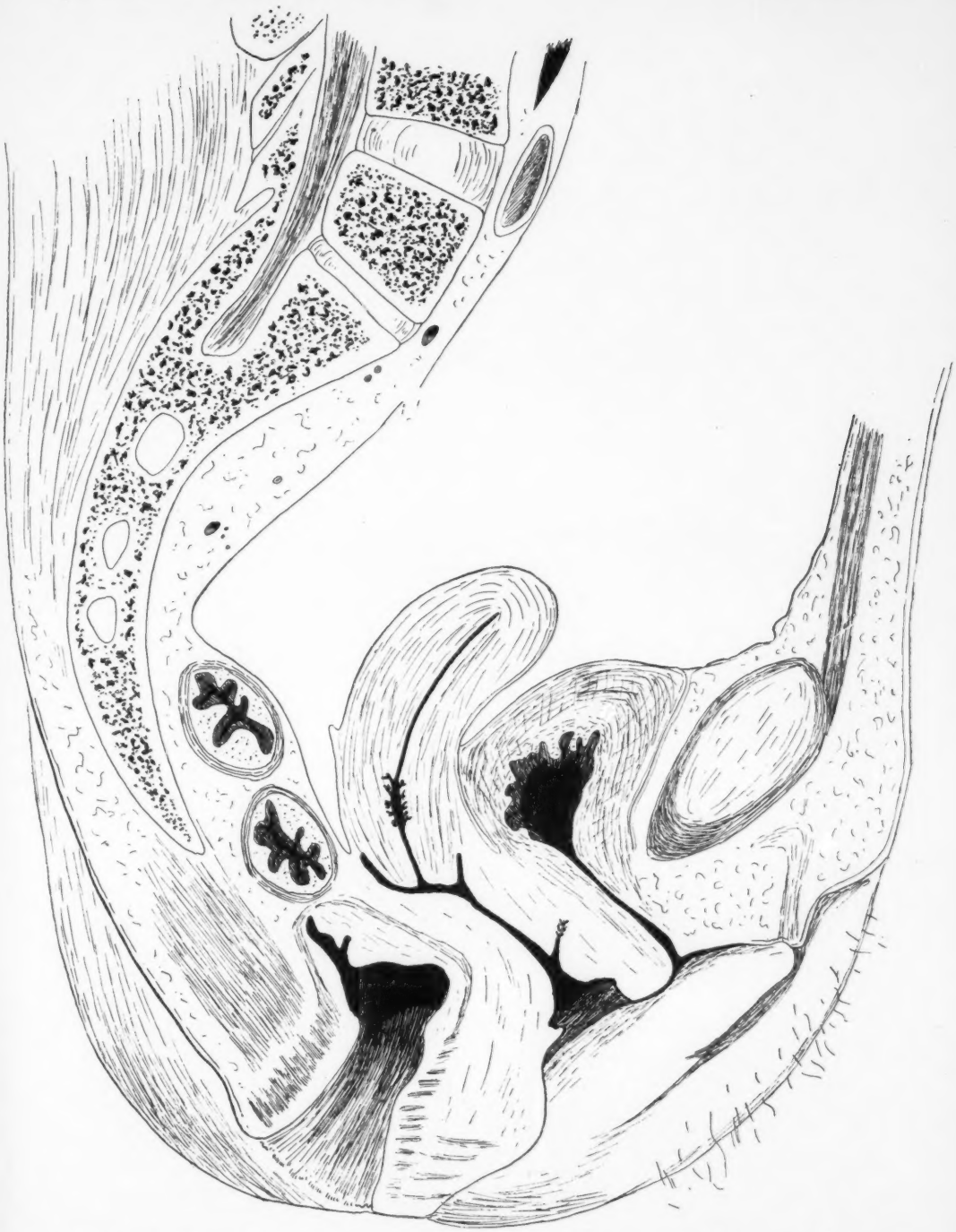


FIG. 2. Median section of the pelvis of a woman 30 years old. The subject was rather fat. From a drawing to scale by Professor Symington.

differences for the two pelves are given in the last column. In future calculations the numbers in this column are used to indicate the effect of moisture on the different measurements. It follows that, in the moist pelvis, all the diameters and the heights of the hip bones are slightly greater than in the dry pelvis.

(5) *The thickness of the soft parts.*

We have been unable to find any very satisfactory record of the thickness of the soft parts of the pelvis. The soft parts affect our calculations. An internal diameter such as the obstetric conjugate measured on the tissue-clothed pelvis must be less than it would be if measured on the moist bony pelvis, by the thickness of the tissues over the sacrum and pubes. An external measurement such as the height of the hip bone is greater on the living subject than on the moist pelvis by the thickness of the tissues above the iliac crest and over the ischium. The thickness of the tissues which increase the height of the hip bone as well as that of the tissues over the ilium in the inter-cristal diameter have been most kindly measured for us by Dr Derry on twenty adult female post-mortem subjects in the manner already described. The details of these measurements will be found in a table at the end of this paper. The averages only are given here.

TABLE VIII.

Inter-cristal diameter		28·63
Thickness of tissues in this diameter	right	·34
	left	·36
Ischio-iliac diameter	right	21·49
	left	21·62
Thickness of tissues *above* crest of ilium	right	·47
	left	·47
Thickness of tissues over ischium ...	right	·49
	left	·47

The inter-cristal diameter on the living subject is therefore greater than that of the moist bony pelvis by ·70 cm., that being the combined thickness of the tissues on the two sides. The ischio-iliac diameter, i.e. the height of the hip, is greater on the living subject by ·47 + ·49 or ·96 cm. on the right side, and ·47 + ·47 or ·94 cm. on the left side.

The tissues over the promontory of the sacrum and the posterior surface of the pubes were not measured. They are almost negligible. Two diagrams drawn to scale and most generously placed at our disposal by Prof. Symington show the differences for a thin and fat subject. In Fig. 1, Plate XXVIII, the median section of a rather thin woman 35 years old, the tissues over the promontory measure 2 mm. while those over the pubes cannot be measured on account of the distended bladder. In Fig. 2, Plate XXIX, showing the left half of the median section of the pelvis of a rather fat woman 30 years old, the tissues over the promontory measure 6 mm., over the pubes 4 mm., i.e. less than over the promontory.

These numbers, however, do not give a good idea of the thickness of the tissues in practice. The tissues would be compressed by the parts of the foetus, and, being composed of loose connective tissue, would take up much less room. If an attempt be made to measure them in a compressed condition the measurement is so small as to be almost negligible, and the chances of error are great. In what follows 1 mm. has been considered a just estimation of the thickness of the tissues over the surfaces of these bones under these conditions. The tissues will therefore diminish the diameters, as measured on the moist bony pelvis, by 2 mm. for the obstetric conjugate, diagonal conjugate and antero-posterior diameter, and will increase the pubic height by 1 mm., if measured internally.

With regard to the transverse diameter at the brim 2 mm. will also be a good allowance. Just at the brim, where this diameter is measured, there is nothing but loose tissue. The external iliac vessels and the psoas muscle are well above the brim, and it seems hardly likely that they can be pushed over it so as to diminish the transverse diameter.

(6) *The finding of the obstetric conjugate and the transverse diameter for the living subject.*

All the necessary information has now been collected for finding formulae to determine the obstetric conjugate and the transverse diameter in the living subject. These formulae can be obtained from the equations previously given by allowing for the effects of moisture and the soft parts. The same letters are used to indicate the lengths of the diameters, but are printed in clarendon to denote the length in the living subject. Consider the obstetric conjugate in the living subject. It is smaller than that of the moist bony pelvis by the thickness of the tissues over the bones, ·2 cm., hence, if this thickness be added to it, we get the obstetric conjugate of the moist bony pelvis. This again is larger than that of the dry pelvis by ·01 cm., the increase due to moisture. If ·01 cm. be subtracted, therefore, the obstetric conjugate is obtained for the dry pelvis. This is expressed by the equation

$$\mathbf{C} + \cdot 20 - \cdot 01 = C.$$

The same argument applies for the diagonal conjugate and antero-posterior and transverse diameters, the equations for which are

$$\mathbf{D} + \cdot 20 - \cdot 13 = D,$$
$$\mathbf{A} + \cdot 20 - \cdot 08 = A,$$
$$\mathbf{T} + \cdot 20 - \cdot 07 = T.$$

With the inter-spinous and inter-cristal diameters, the pubic height, and the height of the hip bone, the case is different. The thickness of the soft parts makes the last three greater in the living subject than on the moist bony pelvis and, to obtain them for the latter, this thickness must be subtracted. It does not, however, affect the inter-spinous diameter for which therefore no correction for soft parts is required. The measurements of the moist bony pelvis are, as with

the other diameters, larger than those of the dry pelvis, so that, to obtain these, the increase due to moisture must also be subtracted. The equations are

$$\mathbf{K} - \cdot 70 - \cdot 14 = K,$$
$$\mathbf{S} - 0 - \cdot 03 = S,$$
$$\mathbf{P} - \cdot 10 - \cdot 22 = P,$$
$$\mathbf{R} - \cdot 96 - \cdot 06 = R,$$
$$\mathbf{L} - \cdot 94 - \cdot 11 = L.$$

If these values for C, D, A, T, K, S, P, R, and L be now substituted in the original formulae (a) to (w), the new formulae produced give the measurements on the living subject. In the following list these are also lettered (a') to (w') to indicate the original formula from which each was derived.

Obstetric conjugate.

(a') $\mathbf{C} = \cdot 978\mathbf{D} - 1 \cdot 675 \pm \cdot 299.$

(b') $\mathbf{C} = \cdot 365\mathbf{A} + 5 \cdot 935 \pm \cdot 705.$

(c') $\mathbf{C} = \cdot 972\mathbf{D} + \cdot 023\mathbf{A} - 1 \cdot 862 \pm \cdot 298.$

(e') $\mathbf{C} = \cdot 110\mathbf{P} + 9 \cdot 785 \pm \cdot 738.$

(f') $\mathbf{C} = \cdot 989\mathbf{D} - \cdot 165\mathbf{P} - 1 \cdot 297 \pm \cdot 293.$

(g') $\mathbf{C} = \cdot 590\mathbf{R} - 1 \cdot 829 \pm \cdot 619.$

(h') $\mathbf{C} = \cdot 602\mathbf{L} - 2 \cdot 132 \pm \cdot 610.$

(i') $\mathbf{C} = 1 \cdot 008\mathbf{D} - \cdot 049\mathbf{R} - 1 \cdot 047 \pm \cdot 298.$

(j') $\mathbf{C} = 1 \cdot 005\mathbf{D} - \cdot 042\mathbf{L} - 1 \cdot 151 \pm \cdot 298.$

Transverse diameter.

(k') $\mathbf{T} = \cdot 305\mathbf{K} + 4 \cdot 710 \pm \cdot 386.$

(l') $\mathbf{T} = \cdot 228\mathbf{S} + 7 \cdot 654 \pm \cdot 415.$

(m') $\mathbf{T} = \cdot 284\mathbf{A} + 9 \cdot 577 \pm \cdot 455.$

(n') $\mathbf{T} = \cdot 261\mathbf{K} + \cdot 049\mathbf{S} + 4 \cdot 513 \pm \cdot 385.$

(o') $\mathbf{T} = \cdot 221\mathbf{K} + \cdot 061\mathbf{S} + \cdot 160\mathbf{A} + 3 \cdot 747 \pm \cdot 374.$

(p') $\mathbf{T} = \cdot 341\mathbf{R} + 5 \cdot 920 \pm \cdot 427.$

(q') $\mathbf{T} = \cdot 320\mathbf{L} + 6 \cdot 328 \pm \cdot 433.$

(r') $\mathbf{T} = \cdot 248\mathbf{K} + \cdot 144\mathbf{R} + 3 \cdot 313 \pm \cdot 378.$

(s') $\mathbf{T} = \cdot 259\mathbf{K} + \cdot 115\mathbf{L} + 3 \cdot 610 \pm \cdot 381.$

(t') $\mathbf{T} = \cdot 169\mathbf{S} + \cdot 221\mathbf{R} + 4 \cdot 522 \pm \cdot 392.$

(u') $\mathbf{T} = \cdot 174\mathbf{S} + \cdot 192\mathbf{L} + 4 \cdot 986 \pm \cdot 398.$

(v') $\mathbf{T} = \cdot 202\mathbf{K} + \cdot 050\mathbf{S} + \cdot 145\mathbf{R} + 3 \cdot 387 \pm \cdot 376.$

(w') $\mathbf{T} = \cdot 217\mathbf{K} + \cdot 047\mathbf{S} + \cdot 113\mathbf{L} + 3 \cdot 723 \pm \cdot 380.$

With this large number of formulae to choose from there should be no difficulty in getting a very close approximation to the lengths of these two non-measurable diameters. Since the desire to attain an end with the least possible exertion is a weakness of human nature, the majority of those who favour these formulae with a trial will, no doubt, wish to use a single measurement, and especially one from which both diameters can be found. Such measurements are the antero-posterior diameter in (b') and (m'), and the height of the hip bone, right in (g') and (p'), left in (h') and (q'). They must not, however, expect such good results as the man who measures the diagonal conjugate and the inter-cristal diameter to obtain the obstetric conjugate from (a) or, more approximately,

$$\mathbf{C} = \cdot 98\mathbf{D} - 1\cdot 68,$$

and the transverse diameter from (k) or, more approximately,

$$\mathbf{T} = \cdot 31\mathbf{K} + 4\cdot 71.$$

With a little extra labour the height of the hip bone can be added to the list. If **H** represent the height of either hip bone in the living subject equations (i') and (j') may be combined to give approximately

$$\mathbf{C} = \mathbf{D} - \cdot 05\mathbf{H} - 1,$$

or

$$\mathbf{C} = (\mathbf{D} - 1) - \tfrac{1}{20}\mathbf{H}.$$

Similarly (r') and (s') may be thrown into the combined form

$$\mathbf{T} = \tfrac{1}{4}(\mathbf{K} + 10) + \tfrac{1}{10}(\mathbf{H} + 10).$$

We thus arrive at the following simple rules:

(i) *To find the obstetric conjugate subtract one-twentieth of the height of either hip bone from the diagonal conjugate diminished by one centimetre.*

(ii) *To find the transverse diameter add one-quarter of the inter-cristal diameter increased by ten centimetres to one-tenth of the height of either hip bone increased by ten centimetres.*

(7) *On the application of the formulae to the pelves of dwarfs.*

It is important to know what reliance can be placed on these formulae in cases of extreme pelvic deformity. In an article on "Dwarfism" by Rischbieth and Barrington (*Treasury of Human Inheritance*, Vol. I, p. 355, 1912) several measurements of dwarfs of various types are recorded. In nine cases measurements of the pelvis are given which include the diagonal conjugate, but in only four of these is the obstetric conjugate also given. The obstetric conjugate has been calculated from the diagonal conjugate for these nine pelves by means of the equation

$$\mathbf{C} = \cdot 98\mathbf{D} + 1\cdot 68$$

with the following results:

Number	Type of case	D	C (observed)	C (calculated)
1	Achondroplasia	7	—	5·18
2	"	9	—	7·14
3	Ateliosis	9·21	7·62	7·35
4	"	8·26	7·62	6·41
5	"	9·95	—	8·07
6	"	8·5	—	6·65
7	Rickety dwarf	7	6·25	5·18
8	" "	8·75	—	6·90
9	Uncertain type	8·47	7·62	6·62

In No. 3 the calculated and measured values are very close, the former being slightly the less, but in 4, 7 and 9 the calculated value is about 1 cm. less than the observed value. In 4 the height of the hip bone was given, so that we were able to find the obstetric conjugate from the equation

$$\mathbf{C} = (\mathbf{D} - 1) - \tfrac{1}{20}\,\mathbf{H}.$$

The value obtained, 6·57, is a little nearer that of the observed value, 7·62, than is the value obtained from the diagonal conjugate alone, 6·41.

The last column shows that all the pelves are of such a degree of contraction as would call for special treatment during pregnancy or labour. The deformity would in most cases need no calculation to make it obvious. Even in extreme contraction, however, the formulae may be useful. In considering the advisability of Caesarian section in such cases, it is necessary to know whether the pelvis will admit the passage of even a dead child. This can be readily ascertained by applying the formulae. The tendency seems to be for them to give too low values in these extreme cases. With the present-day results of Caesarian section this is to err on the safe side for both the mother and the child.

SUMMARY.

1. Methods for obtaining the height of the hip bone on the living subject and for measuring the thickness of the tissues over different parts of this bone on the corpse, have been described.

2. The averages and variability of the pelvic measurements have been found and the various measurements correlated. The obstetric and diagonal conjugates show very high correlation. The inter-cristal is the diameter most closely correlated with the transverse diameter. Both the obstetric conjugate and the transverse diameter show good correlation with the height and breadth of the hip bone. Corresponding measurements on the two hip bones are more highly correlated than two measurements on the same bone.

3. Formulae have been obtained for finding the obstetric conjugate and the transverse diameter on the dry pelvis. The former may be found best from the diagonal conjugate, singly or combined with the antero-posterior diameter, the height of the hip bone, or the pubic height. The transverse diameter is found from the inter-cristal diameter, taken by itself or combined with one or two of the following: inter-spinous diameter, antero-posterior diameter, height of hip bone. The formulae were tested and found to give good results for the modern English female pelvis.

4. Pelves were measured dry and after immersion in water to study the effects of moisture. All the diameters and the heights of the hip bones are slightly greater in the moist than in the dry pelvis.

5. The way in which the soft tissues affect the measurements has been pointed out. The thickness of the tissues over the bones bounding the internal diameters is almost negligible.

6. Finally formulae have been arrived at for finding the obstetric conjugate and the transverse diameter in the living subject. The simplest of these, for the obstetric conjugate, are approximately

$$\mathbf{C} = \cdot 98\mathbf{D} - 1\cdot 68,$$

$$\mathbf{C} = (\mathbf{D} - 1) - \tfrac{1}{20}\mathbf{H},$$

and, for the transverse diameter,

$$\mathbf{T} = \cdot 31\mathbf{K} + 4\cdot 71,$$

$$\mathbf{T} = \tfrac{1}{4}(\mathbf{K} + 10) + \tfrac{1}{10}(\mathbf{H} + 10),$$

where **D** is the length of the diagonal conjugate, **K** that of the inter-cristal diameter, and **H** the height of either hip bone.

In conclusion I wish to thank Prof. Karl Pearson and all those who have so generously come to my help—Prof. Symington for placing his diagrams at my disposal, Prof. Thane and Dr Derry for the loan of pelves, Dr Derry and Dr Braxton Hicks for their measurements on post-mortem subjects, and Mr Soper for the useful little instrument with which most of these measurements were made. To Prof. Pearson is due whatever merit this work may possess. It has been carried out under his guidance without which it could never have been attempted.

APPENDIX I.

Measurements of five pelves used for testing formulae. I and II ancient Egyptian female. III ancient Egyptian male. IV modern English female. V modern English male. In IV and V the bones were connected together by the ligaments.

TABLE A.

Measurement	I	II	III	IV	V
Inter-crests	22·30	24·92	28·28	26·26	26·54
Inter-spines	19·81	21·25	27·75	21·40	23·29
Transverse	11·33	11·67	12·55	12·85	11·63
Diagonal conjugate ...	11·18	10·75	12·68	14·14	12·70
Obstetric conjugate ...	10·71	9·35	10·57	12·42	10·32
Antero-posterior ...	10·42	11·03	10·88	10·11	10·71
Pubic height	2·32	3·88	4·47	3·72	4·20
Right hip—height ...	17·40	17·98	20·55	19·03	21·55
„ „ breadth ...	14·29	14·32	15·41	15·78	15·87
Left hip—height ...	17·60	17·87	20·62	18·79	21·70
„ „ breadth ...	14·02	14·49	15·80	15·77	15·87
Sacrum—height ...	8·72	9·35	10·93	—	—
„ breadth ...	10·30	10·85	11·83	—	—

Table of measurements taken by Dr Derry from 20 adult female post-mortem subjects to show the thickness of the soft parts.

TABLE B.

Age	Inter-cristal diameter	Thickness of tissues in this diameter		Ischio-iliac diameter		Thickness of tissues *above* crest of ilium		Thickness of tissues over ischium		Remarks
		R	*L*	*R*	*L*	*R*	*L*	*R*	*L*	
61	31·15	·65	·79	19·95	20·00	·45	·55	·50	·55	not very fat but well nourished
35	26·35	·48	·49	19·75	19·60	·55	·60	·50	·40	„ „ „
18	28·50	·45	·40	20·00	19·90	·39	·40	·60	·46	„ „ „
56	29·00	·55	·50	23·00	23·00	·80	·80	·50	·45	„ „ „
57	28·50	·55	·60	23·20	23·55	1·00	·85	·55	·45	stout
54	25·00	·40	·40	20·30	20·35	·55	·45	·50	·50	slight layer of fat only
55	28·95	·35	·40	21·15	21·65	·50	·50	·50	·45	„ „ „
62	32·70	·30	·30	22·95	23·00	·40	·45	·50	·70	thin
31	26·95	·20	·10	20·50	20·40	·30	·20	·40	·45	*very* emaciated
65	28·50	·20	·35	21·00	21·20	·30	·45	·25	·30	thin
28	28·75	·20	·20	21·20	21·40	·35	·35	·40	·30	emaciated
59	30·30	·35	·35	23·00	23·00	·35	·35	·40	·50	thin
20	28·50	·30	·30	21·70	21·90	·60	·50	·60	·55	thin layer of fat
55	27·30	·40	·50	22·00	22·50	·50	·55	·60	·65	fat
39	29·10	·30	·25	21·05	21·35	·45	·40	·50	·45	thin
28	30·30	·35	·35	22·35	22·40	·35	·40	·40	·30	fairly fat
38	30·25	·20	·30	22·45	22·85*	·40	·45	·55	—*	thin
45	27·10	·10	·20	22·30	22·25	·45	·40	·60	·60	„
22	26·10	·20	·15	21·25	21·35	·25	·25	·60	·55	„
43	29·30	·20	·20	20·75	20·75	·40	·40	·40	·40	„

* Some swelling over ischium.

APPENDIX II.

CORRELATION TABLES OF THE DIAMETERS WITH ONE ANOTHER.

TABLE I. Inter-cristal.

Obstetric conjugate.

	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	27·25—	27·75—	28·25—	28·75—	Totals
7·25—	—	—	—	—	—	—	—	1	0·5	—	—	—	—	—	—	—	—	1·5
7·75—	—	—	—	—	—	—	—	—	0·5	—	1	2	—	—	—	—	—	3·5
8·25—	1	—	1	—	1	—	—	2	—	—	1	0·5	0·5	—	—	—	—	7
8·75—	—	—	—	—	1	1	3·5	1·5	6	3·5	6·5	—	4	0·5	1	1	—	29·5
9·25—	—	—	1	—	1	—	2	4	2·5	3	3	5	1·5	1·5	—	—	—	24·5
9·75—	—	—	—	—	1·5	—	3	1·5	5	6·5	6	2·5	5·75	1·25	4	3	—	40
10·25—	—	—	1	—	0·5	0·25	2·25	0·5	5·5	4	5	3	4·25	3·75	2	—	—	32
10·75—	—	—	—	—	3	0·25	5·25	3	3·5	3·5	6	1·5	5·25	1·75	4	1	—	38
11·25—	—	—	—	—	—	0·25	0·25	—	3	1	3	1	6·25	2·25	—	1	—	18
11·75—	—	—	—	—	—	1·25	0·25	3	2	2	2·5	2	—	0·5	0·5	—	1	15
12·25—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	2
12·75—	—	—	—	—	—	—	—	—	1	1	0·5	0·5	1	—	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Totals	1	0	3	0	8	3	16·5	16·5	30·5	24·5	34·5	18	28·5	12·5	12·5	6	1	216

TABLE II. Transverse.

10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—
—	—	—	1	—	0·5	—	—	—
—	—	—	—	1	2·5	—	—	—
1	—	—	1	1	3	1	—	—
—	—	1	6	4	11	3	4·5	—
—	1	1	2	5·5	8	3·5	3	0·5
—	—	1	3·5	4·5	13	9	7·75	1·25
—	—	0·25	2·75	5·5	12	5	4·25	2·25
1	—	3·25	8·75	4·5	9	7·5	2	2
—	—	—	1	3	8·5	3·5	1	1
—	—	—	2	0·5	6·5	5	1	—
—	—	—	—	—	1	—	1	—
—	—	—	—	—	4	—	—	—
—	—	—	—	—	—	—	—	—
—	—	—	1	—	—	—	—	—
2	1	6·5	29	29·5	79	37·5	24·5	7

TABLE III. Inter-spinous.

Obstetric conjugate.

	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	Totals
7·25—	—	—	—	—	—	—	—	—	—	—	1	—	—	0·5	—	—	—	—	—	—	—	1·5
7·75—	—	—	—	—	—	—	—	—	—	—	0·5	0·5	1	0·5	1	—	—	—	—	—	—	3·5
8·25—	1	—	—	—	1	—	—	—	1·5	0·5	1	—	—	1·5	0·5	—	—	—	—	—	—	7
8·75—	—	—	—	—	1	2	1	—	2	2·5	2	6	4	3	3	1	2	—	—	—	—	29·5
9·25—	0·5	0·5	—	—	—	—	1	2	1	0·5	6	3	2	5·5	0·5	1	1	—	—	—	—	24·5
9·75—	—	—	—	—	—	—	1	2·25	4·25	2	5·25	1·25	4	5	6·25	3·75	1·5	2·5	1	—	—	40
10·25—	—	—	—	—	—	—	1·5	1·25	1·25	2	8·25	0·75	3	2	4·25	3·75	2·5	1·5	—	—	—	32
10·75—	—	—	—	—	1	2	3·5	2	1	4	7	1·5	3·5	3	7	—	0·25	1·25	—	—	1	38
11·25—	—	—	—	—	—	—	—	0·25	1·25	2	1·5	1·5	2·5	1·25	2·75	1·5	0·25	1·25	0·5	1·5	—	18
11·75—	—	—	—	—	—	—	—	2·25	1·25	1·5	3·5	2	2	0·25	1·25	—	1	—	—	—	—	15
12·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
12·75—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	—	1	—	—	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	1·5	0·5	0	0	3	4	8	10	13·5	15	36	16·5	24	23·5	28·5	12	9·5	6·5	1·5	1·5	1	216

TABLE IV. Diagonal conjugate.

TABLE V. Antero-posterior.

TABLE IV. Diagonal conjugate.

Obstetric conjugate.

	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	Totals
9·25—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	2
9·75—	0·5	1·5	3	1	—	—	—	—	—	—	—	—	—	—	6
10·25—	—	1	2	2	1	—	—	—	—	—	—	—	—	—	6
10·75—	—	—	2	5	4	—	—	—	—	—	—	—	—	—	26
11·25—	—	—	—	9	14	1·75	0·25	—	—	—	—	—	—	—	40·5
11·75—	—	—	—	1·5	6	6	—	—	—	—	—	—	—	—	41
12·25—	—	—	—	1	4·5	13·5	7·5	—	—	—	—	—	—	—	35·5
12·75—	—	—	—	—	1	14·25	14·75	0·5	—	—	—	—	—	—	27·5
13·25—	—	—	—	—	—	5	—	5	3·75	7·75	2	—	—	—	19·5
13·75—	—	—	—	—	—	—	—	—	2	2	—	—	—	—	5
14·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
14·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Totals	2	6	6	26	40·5	41	35·5	27·5	19·5	5	5	2	1·5	1	216

TABLE V. Antero-posterior.

	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	Totals
8·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
9·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·5
9·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3·5
10·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
10·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29·5
11·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	24·5
11·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40
12·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	32
12·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	38
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18
13·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15
14·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
14·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
15·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
15·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals	1	2	7	24·5	49	40	39·5	28·5	16·5	5·5	1·5	1				216

TABLE VI. Inter-tuberal.

Obstetric conjugate.

	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	Totals
7·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·5
7·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3·5
8·25—	—	—	—	4	—	—	1	2	5	4	1	1	—	—	—	7
8·75—	—	—	2	5	1·5	6	6	5	2	1·5	0·5	—	—	—	—	29·5
9·25—	—	—	—	2	6·5	5	5	5	—	—	—	0·5	0·5	—	—	24·5
9·75—	—	—	—	5	6·5	7·5	9	7	3	1	—	1	—	—	—	40
10·25—	—	—	—	1	6	3·5	7·5	5	7	2	—	—	—	—	—	32
10·75—	—	2	—	2	9	4	12	4	4	1	—	—	—	—	—	38
11·25—	2·5	—	1	—	—	2	5·5	5	—	1·5	0·5	—	—	—	—	18
11·75—	0·5	1·5	4	1·5	4	2	1	5	1	—	—	—	—	—	—	15
12·25—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
12·75—	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Totals	9	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5					216

TABLE VII. Posterior sagittal.

Obstetric conjugate.

	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	Totals
6·25—	—	0·5	1·5	1	8	5	1·5	4·5	—	—	29
6·75—	—	—	1	3	8	6	12·5	4·5	3	—	47
7·25—	—	—	—	1	6·5	3·5	14	7·5	10·5	—	53
7·75—	—	1	2	—	2	5	7·5	11·5	2·5	—	43·5
8·25—	—	—	—	1	2	2	4	1·5	2·5	—	20·5
8·75—	—	—	—	—	—	2	2	2	3	—	11
9·25—	—	—	—	—	1	—	1	2	—	—	4
9·75—	—	—	—	—	—	—	—	—	—	—	0
10·25—	—	—	—	—	—	—	1	—	—	—	1
10·75—	—	—	—	—	—	—	—	—	—	—	0
11·25—	—	—	—	—	—	—	—	1	—	—	1
Totals	6	29	8	6	29·5	24·5	40	32	38	18	216

TABLE VIII. Obstetric conjugate.

Pubic height.	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	Totals
0·75—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	2
1·25—	—	—	—	—	1	—	1	1	—	—	—	—	—	—	3
1·75—	—	—	1	3	2	4	6	4	1	2	—	—	—	—	23
2·25—	0·5	1·5	3	6	7	11·5	9·5	12	5	2	—	3·5	—	—	61·5
2·75—	1	1	2	18·5	9·5	18	7	11	8	3·5	2	0·5	—	1	83
3·25—	—	1	—	1	3	4·5	7	9·5	4	4·5	—	—	—	—	34·5
3·75—	—	—	—	1	1	1	—	—	—	1	—	—	—	—	4
4·25—	—	—	—	—	—	—	0·5	0·5	—	—	—	—	—	—	1
Totals	1·5	3·5	6	29·5	23·5	40	32	38	18	13	2	4	0	1	212

TABLE IX. Transverse.

10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—
—	—	—	2	—	—	—	—	—
1	—	—	—	—	0·5	1·5	—	—
—	—	2	3	1	10	4·5	2·5	—
1	1	—	6·5	10·5	28·5	5	8	1
—	—	2	12	12·75	27·75	17·5	9·5	1·5
—	—	2	4	4·75	9·75	6	4	4
—	—	—	1	0·5	1·5	1	—	—
—	—	0·5	0·5	—	—	—	—	—
2	1	6·5	29	29·5	78	35·5	24	6·5

TABLE X. Inter-cristal.

Pubic height.	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	27·25—	27·75—	28·25—	28·75—	Totals
0·75—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2
1·25—	—	—	—	—	1	—	—	—	—	—	—	—	—	2	—	—	—	3
1·75—	—	—	—	—	—	1	4	2	7·5	3	2·5	1	2	—	—	—	—	23
2·25—	1	—	—	—	2	1	8	2·5	13	7	12·5	4	6·5	2	2	—	—	61·5
2·75—	—	—	2	—	4	—	3·5	5·75	7·25	8·5	15	6·5	16	5·5	5	4	—	83
3·25—	—	—	—	—	1	0·5	0·5	3·25	2·75	5	4	4·5	3·5	2·5	4	2	1	34·5
3·75—	—	—	—	—	—	—	—	1	—	—	—	1	—	0·5	1·5	—	—	4
4·25—	—	—	—	—	—	0·5	0·5	—	—	—	—	—	—	—	—	—	—	1
Totals	1	0	3	0	8	3	16·5	15·5	30·5	23·5	34	17	28	12·5	12·5	6	1	212

TABLE XI. Inter-spinous.

Pubic height.	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	Totals
0·75—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	2
1·25—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	3
1·75—	—	—	—	—	1	1	—	3	4	2	4	1	5	1	—	1	—	—	—	—	—	23
2·25—	1	—	—	—	1	1	2	4	3·5	2·5	12·5	7	8·5	8	6·5	3	1	—	—	—	—	61·5
2·75—	0·5	0·5	—	—	1	—	3	0·5	2·5	7	12·5	5	9·5	11	15·5	5·5	4	4	0·5	0·5	—	83
3·25—	—	—	—	—	—	1	1	1·5	1·5	3·5	5	2·5	1	3	5	1·5	3·5	1·5	1	1	1	34·5
3·75—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	1	1	—	—	—	—	—	4
4·25—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals	1·5	0·5	0	0	3	4	8	9	12·5	15	35	16·5	24	23	28	12	9·5	6·5	1·5	1·5	1	212

TABLE XII. Diagonal conjugate.

7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
—	—	—	—	—	1	1	—	—	—	—	—	2
—	—	—	—	1	—	1	1	—	—	—	—	3
—	—	1	3	2	4	6	4	1	2	—	—	23
0·5	1·5	3	6	7	11·5	9·5	12	5	2	—	3·5	61·5
1	1	2	18·5	9·5	18	7	11	8	3·5	2	0·5	83
—	1	—	1	3	4·5	7	9·5	4	4·5	—	—	34·5
—	—	—	1	1	1	—	—	—	1	—	—	4
—	—	—	—	—	—	0·5	0·5	—	—	—	—	1
1·5	3·5	6	29·5	23·5	40	32	38	18	13	2	4	212

TABLE XIII. Antero-posterior.

10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
—	—	2	—	—	—	—	—	—	2
1	—	—	—	0·5	1·5	—	—	—	3
—	2	3	1	10	4·5	2·5	—	—	23
1	—	6·5	10·5	28·5	5	8	1	—	61·5
—	2	12	12·75	27·75	17·5	9·5	1·5	—	83
—	2	4	4·75	9·75	6	4	4	—	34·5
—	—	1	0·5	1·5	1	—	—	—	4
—	0·5	0·5	—	—	—	—	—	—	1
2	6·5	29	29·5	78	35·5	24	6·5	—	212

Totals	1·5	0·5	0	0	3	4	8	9	12·5	15	35	16·5	24	23	28	12	9·5	6·5	1·5	1·5	1	212

TABLE XII. Diagonal conjugate.

Pubic height.	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
0·75—	—	—	—	—	1	1	—	—	—	—	—	—	2
1·25—	—	—	—	—	1	—	1	1	—	—	—	—	3
1·75—	—	1	1	1	5	8	3	1	3	—	—	—	23
2·25—	—	2	5	10	9	12	9	5	6	1	1·5	1	61·5
2·75—	2	2	—	13	17	14·5	13	12·5	4·5	2	1·5	1	83
3·25—	—	1	—	1	4	4	9·5	7	6	1	1	—	34·5
3·75—	—	—	—	—	2	1	—	—	—	—	1	—	4
4·25—	—	—	—	—	0·5	0·5	—	—	—	—	—	—	1
Totals	2	6	6	25	39·5	41	35·5	26·5	19·5	4	5	2	212

TABLE XIII. Antero-posterior.

	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	Totals
0·75—	—	—	—	—	1	1	—	—	—	—	—	2
1·25—	—	—	—	—	—	1	1	—	—	0·5	0·5	3
1·75—	—	—	2	4	2·5	4·5	7	2	1	—	—	23
2·25—	—	—	2	11·5	13	9	11	9·75	3·25	1	1	61·5
2·75—	1	2	1·5	8·5	20	16·5	11·5	12·75	7·25	2	—	83
3·25—	—	—	1·5	0·5	8·5	7	8	3	5	1	—	34·5
3·75—	—	—	—	—	1	1	—	1	—	1	—	4
4·25—	—	—	—	—	1	—	—	—	—	—	—	1
Totals	1	2	7	24·5	47	40	38·5	28·5	16·5	5·5	1·5	212

TABLE XIV. Inter-tuberal.

Pubic height.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	Totals
0·75—	—	—	—	1	—	1	—	—	—	—	2
1·25—	—	1	—	—	1	—	1	—	—	—	3
1·75—	—	2	3	5	6	5	2	—	—	—	23
2·25—	3	4	11	6	19·5	7	8	2	1	—	61·5
2·75—	4	11	14	14	17	15	6	1·5	0·5	—	83
3·25—	1	2	8	6	5·5	7	2	2	—	1	34·5
3·75—	1	0·5	0·5	1	—	1	—	—	—	—	4
4·25—	—	—	—	—	1	—	—	—	—	—	1
Totals	9	20·5	36·5	33	50	36	19	5·5	1·5	1	212

TABLE XV. Posterior sagittal.

	5·75—	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—
0·75—	—	—	1	1	—	—	—	—	—	—	—	—
1·25—	—	—	—	2	—	—	—	—	—	1	—	—
1·75—	1	1	7	8	4	1	1	—	—	—	—	—
2·25—	2	11·5	8·5	13	10·5	10	2	4	—	—	—	—
2·75—	3	9·5	22	23·5	16	6	2	—	—	—	—	1
3·25—	—	5	6·5	5	10	3	5	—	—	—	—	—
3·75—	—	1	1	0·5	1	0·5	—	—	—	—	—	—
4·25—	—	—	—	—	1	—	—	—	—	—	—	—
Totals	6	28	46	53	42·5	20·5	10	4	0	1	0	1

TABLE XVI. Inter-cristal.

Transverse.	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	27·25—	27·75—	28·25—	28·75—	Totals
10·25—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2
10·75—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
11·25—	—	—	1	—	—	0·25	2·25	1	1	1	—	—	—	—	—	—	—	6·5
11·75—	—	—	2	—	3	0·25	6·25	7	5·25	0·25	1	1	1	1	—	—	—	29
12·25—	—	—	—	—	2	—	3·5	3·75	1	4·25	5·5	3·5	4·5	—	1·5	—	—	29·5
12·75—	—	—	—	—	1	2·5	3·5	2·25	18·75	11	16·25	7·75	12	1·5	2·5	—	—	79
13·25—	—	—	—	—	—	—	1	2	4	4·5	7·25	3·25	5·5	5·5	1·5	3	—	37·5
13·75—	—	—	—	—	—	—	—	0·5	0·5	3·5	4·25	2·25	5·25	1·25	3	3	1	24·5
14·25—	—	—	—	—	—	—	—	—	—	—	0·25	0·25	0·25	3·25	3	—	—	7
Totals	1	0	3	0	8	3	16·5	16·5	30·5	24·5	34·5	18	28·5	12·5	12·5	6	1	216

TABLE XVII. Inter-spinous.

Transverse.	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	Totals
10·25—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
10·75—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
11·25—	0·5	0·5	—	—	1	1	0·5	1	—	1	1	—	—	—	—	—	—	—	—	—	—	6·5
11·75—	—	—	—	—	—	—	4·5	0·5	5·5	3·5	6·75	2·25	2	1	2	—	1	—	—	—	—	29
12·25—	—	—	—	—	—	1	1	1	1·5	2·5	7·25	2·25	0·5	6·75	3·5	1·25	—	1	—	—	—	29·5
12·75—	—	—	—	—	2	1	1	4	2·5	6	13	8·75	13·75	9·75	8·5	7·25	1	0·5	—	—	—	79
13·25—	—	—	—	—	—	—	1	2	2	1	6	3·25	5·25	2·5	6	1·5	2	4	—	—	1	37·5
13·75—	—	—	—	—	—	—	—	0·5	1·5	1	2	—	2·5	2·5	7·5	2	3·5	0·5	0·5	0·5	—	24·5
14·25—	—	—	—	—	—	—	—	—	0·5	—	—	—	—	1	1	—	2	0·5	1	1	—	7
Totals	1·5	0·5	0	0	3	4	8	10	13·5	15	36	16·5	24	23·5	28·5	12	9·5	6·5	1·5	1·5	1	216

TABLE XVIII. Diagonal conjugate.

Transverse.	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
10·25—	—	—	1	—	—	—	—	1	—	—	—	—	2
10·75—	—	—	—	—	—	1	—	—	—	—	—	—	1
11·25—	—	—	—	2	0·25	2·25	1	1	—	—	—	—	6·5
11·75—	1	1	—	3	7·25	3·25	5·5	4	3	—	—	1	29
12·25—	—	1	2	3	6·5	5·5	5	6	0·5	—	—	—	29·5
12·75—	1	4	2	9	15	13·5	9	8·5	12	2	2	1	79
13·25—	—	—	—	6	6	6·5	8	5	1	3	2	—	37·5
13·75—	—	—	1	3	5	6·5	5	1	2	—	1	—	24·5
14·25—	—	—	—	—	0·5	2·5	2	1	1	—	—	—	7
Totals	2	6	6	26	40·5	41	35·5	27·5	19·5	5	5	2	216

TABLE XIX. Antero-posterior.

8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—
—	—	0·5	0·5	—	1	—	—	—	—	—	—
—	—	—	1	—	—	—	—	—	—	—	—
—	—	2	1	2·5	1	—	—	—	—	—	—
—	1	0·5	3	8·5	9	5	—	2	—	—	—
—	—	0·5	7	3·75	4·75	6	6·5	—	1	—	—
0·5	1	3·5	8·5	20·25	15·75	10·5	13	4·5	1·25	0·25	—
0·5	—	—	2	8·5	5·5	10	5	4·5	1·25	0·25	—
—	—	—	1·5	5	3	8	1	3·5	1	1	0·5
—	—	—	—	0·5	—	—	3	2	1	—	0·5

Totals
2
1
6·5
29
29·5
79
37·5
24·5
7
216

Totals
1
2
7
24·5
49
40
39·5
28·5
16·5
5·5
1·5
1

TABLE XX. Inter-tuberal.

TABLE XXI. Posterior sagittal.

TABLE XX. Inter-tuberal.

Transverse.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
10·25—	—	1	—	—	—	—	1	—	—	—	—	2
10·75—	—	—	—	—	—	1	—	—	—	—	—	1
11·25—	—	2	1	—	2·5	—	1	—	—	—	—	6·5
11·75—	3	6	5·5	5	5·5	3	1	—	—	—	—	29
12·25—	3	3	6·5	7·5	4	1·5	4	—	—	—	—	29·5
12·75—	2	5	15	11·5	24	13·5	6	1	1	—	—	79
13·25—	1	1·5	8	4	7	11	2	2·5	0·5	—	—	37·5
13·75—	—	2	1·5	5	6	4·5	3	2	—	0·25	0·25	24·5
14·25—	—	—	—	—	1	2·5	1	1	—	1·25	0·25	7
Totals	9	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5	216

TABLE XXI. Posterior sagittal.

5·75—	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—
—	—	1	1	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—
—	1	4	—	1·5	—	—	—	—	—	—	—
1	4	9	6·5	6·5	1	—	1	—	—	—	—
1	5	4·5	6·75	5·75	4·5	—	1	—	—	—	1
2	12	19	16·25	14·75	8·5	5	1	—	0·5	—	—
1	3	4·5	14	9	2·5	3	—	—	0·5	—	—
—	3·5	5	7·5	3·5	3	1	1	—	—	—	—
—	0·5	—	1	2·5	1	2	—	—	—	—	—
6	29	47	53	43·5	20·5	11	4	0	1	0	1

TABLE XXII. Diagonal conjugate.

Inter-spinous.	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
16·75—	—	—	1	0·5	—	—	—	—	—	—	—	—	1·5
17·25—	—	—	—	0·5	—	—	—	—	—	—	—	—	0·5
17·75—	—	—	—	—	—	—	—	—	—	—	—	—	0
18·25—	—	—	—	—	—	—	—	—	—	—	—	—	0
18·75—	—	—	1	1	—	1	—	—	—	—	—	—	3
19·25—	—	—	—	1	1	—	—	2	—	—	—	—	4
19·75—	—	—	—	—	3·5	2·5	2	—	—	—	—	—	8
20·25—	—	—	—	—	2	2	3	0·5	1·5	1	—	—	10
20·75—	—	1·5	—	1	5	1	1	2·5	0·5	—	1	—	13·5
21·25—	—	0·5	—	1	1	4	3	3	1·5	—	1	—	15
21·75—	1	1	1·5	3	6	8·5	5·5	5	4·5	—	—	—	36
22·25—	—	—	0·5	5	5	1·5	1	1·5	2	—	—	—	16·5
22·75—	1	1	1	2	3	5·5	3·5	1·5	2·5	2	1	—	24
23·25—	—	1	1	5·5	5·5	4	3·5	0·25	1·75	—	—	1	23·5
23·75—	—	1	—	1·5	4·5	4·5	7	5·75	4·25	—	—	—	28·5
24·25—	—	—	—	1	3	3	1·5	1·5	—	1	1	—	12
24·75—	—	—	—	2	1	1·5	2	—	1	—	1	1	9·5
25·25—	—	—	—	1	—	1	2·5	1	—	1	—	—	6·5
25·75—	—	—	—	—	—	1	—	0·5	—	—	—	—	1·5
26·25—	—	—	—	—	—	—	—	1·5	—	—	—	—	1·5
26·75—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	2	6	6	26	40·5	41	35·5	27·5	19·5	5	5	2	216

TABLE XXIII. Antero-posterior.

8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—
—	—	0·5	0·5	0·5	—	—	—	—	—	—	—
—	—	—	—	0·5	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	2	—	1	—	—	—	—	—	—	—
—	—	—	—	1	2	1	—	—	—	—	—
—	—	—	3	3	2	—	—	—	—	—	—
—	—	0·25	2·25	2	1·5	2	1	1	—	—	—
—	—	0·5	2·5	2	1·5	3·5	1·5	—	1	—	1
—	1	0·25	1·25	1	5·5	2	3	1	—	—	—
—	—	1	5·5	10	8·5	6	2	2	1	—	—
—	—	1	2·5	2	4·5	2	1·5	2	1	—	—
—	—	—	2	5·5	4·5	7·25	3·75	1	—	—	—
—	1	—	2	5·5	5·5	4·25	4·25	1	—	—	—
—	—	0·25	2·5	8·5	2·75	4	6·5	2	1	1	—
—	—	1·25	0·5	3·5	1·25	2	2	1·5	—	—	—
—	—	—	—	1·5	0·5	2·5	2	2	0·5	0·5	—
1	—	—	—	1·5	—	2	1	1	—	—	—
—	—	—	—	—	—	—	—	1·5	—	—	—
—	—	—	—	—	—	—	—	0·5	1	—	—
—	—	—	—	—	—	1	—	—	—	—	—
1	2	7	24·5	49	40	39·5	28·5	16·5	5·5	1·5	1

TABLE XXIV.

Inter-tuberal.

Inter-spinous.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
16·75—	—	1	0·5	—	—	—	—	—	—	—	—	1·5
17·25—	—	—	0·5	—	—	—	—	—	—	—	—	0·5
17·75	—	—	—	—	—	—	—	—	—	—	—	0
18·25—	—	—	—	—	—	—	—	—	—	—	—	0
18·75—	—	2	—	—	1	—	—	—	—	—	—	3
19·25—	—	—	—	—	1	1	2	—	—	—	—	4
19·75—	1	1	1	1	2	2	—	—	—	—	—	8
20·25—	—	—	4	—	1	3	2	—	—	—	—	10
20·75—	—	2·5	2·5	2·5	3	1	1	—	—	0·5	0·5	13·5
21·25—	—	1	2·5	2·5	4	3	1	1	—	—	—	15
21·75—	—	3·5	6	6	13	3·5	3	1	—	—	—	36
22·25—	1·5	1·5	2	2	3	4·5	2	—	—	—	—	16·5
22·75—	0·5	1	7·5	6	3	3·5	1·5	—	1	—	—	24
23·25—	1·5	2	5	6	6	2	0·5	0·5	—	—	—	23·5
23·75—	2·5	3	2	3·5	5·5	6	4	2	—	—	—	28·5
24·25—	1	—	2	0·5	4·5	2	0·5	1	0·5	—	—	12
24·75—	—	1	0·5	1	2	3·5	1·5	—	—	—	—	9·5
25·25—	—	1	1·5	1	1	2	—	—	—	—	—	6·5
25·75—	—	—	—	0·5	—	—	—	—	—	1	—	1·5
26·25—	—	—	—	0·5	—	—	—	1	—	—	—	1·5
26·75—	1	—	—	—	—	—	—	—	—	—	—	1
Totals	9	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5	216

TABLE XXV.

Posterior sagittal.

5·75—	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—
—	—	1	—	0·5	—	—	—	—	—	—	—
—	—	—	—	0·5	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
1	1	—	1	—	—	—	—	—	—	—	—
—	—	1	1	1	—	—	1	—	—	—	—
2	2	1	2	1	—	—	—	—	—	—	—
1	—	2	3·5	0·5	2	1	—	—	—	—	—
—	—	3	4·5	4	1	1	—	—	—	—	—
—	2	5·5	3	2	0·5	2	—	—	—	—	—
—	6·5	10	7·5	8	2	1	—	—	—	—	1
1	2	3·5	4	4	—	1	1	—	—	—	—
—	3	5	5·5	5·5	3	1	1	—	—	—	—
—	3·5	6	5·5	4	3·5	1	—	—	—	—	—
—	4	7	7	6	3·5	—	1	—	—	—	—
1	2	2	4	1	2	—	—	—	—	—	—
—	2	—	1·5	3·5	0·5	1	—	—	1	—	—
—	1	—	2	1	1·5	1	—	—	—	—	—
—	—	—	0·5	—	1	—	—	—	—	—	—
—	—	—	0·5	—	—	1	—	—	—	—	—
—	—	—	—	1	—	—	—	—	—	—	—
6	29	47	53	43·5	20·5	11	4	0	1	0	1

TABLE XXVI.

Inter-cristal.

Inter-spinous.

	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	27·25—	27·75—	28·25—	28·75—	Totals
16·75—	1	—	0·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·5
17·25—	—	—	0·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·5
17·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
18·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
18·75—	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	3
19·25—	—	—	—	—	1	1	1	1	—	—	—	—	—	—	—	—	—	4
19·75—	—	—	1	—	1	0·5	3·5	1	—	0·5	0·5	—	—	—	—	—	—	8
20·25—	—	—	—	—	1·5	0·25	2·25	1	2	3	—	—	—	—	—	—	—	10
20·75—	—	—	1	—	1	0·25	5·25	0·5	1·5	1	1·5	0·5	—	0·5	0·5	—	—	13·5
21·25—	—	—	—	—	1·5	—	0·5	1·5	5·5	1	2	1	1	1	—	—	—	15
21·75—	—	—	—	—	1	1	2	8·5	7·25	6·75	7	1·5	1	—	—	—	—	36
22·25—	—	—	—	—	—	—	1	2	3·75	2·25	3·25	2·25	2	—	—	—	—	16·5
22·75—	—	—	—	—	—	—	—	—	6	5	4·75	4·75	2·5	1	—	—	—	24
23·25—	—	—	—	—	—	—	—	—	3·5	4·5	6	1·75	5·75	—	2	—	—	23·5
23·75—	—	—	—	—	—	—	—	—	1	0·5	8·5	4·75	6·25	1·5	6	—	—	28·5
24·25—	—	—	—	—	—	—	—	—	—	—	0·75	1·25	7	1·5	1	0·5	—	12
24·75—	—	—	—	—	—	—	—	—	—	—	0·25	0·25	1·25	3·25	1	2·5	1	9·5
25·25—	—	—	—	—	—	—	—	—	—	—	—	—	1·75	2·75	1	1	—	6·5
25·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0·5	—	1·5
26·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	0·5	—	1·5
26·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Totals	1	0	3	0	8	3	16·5	16·5	30·5	24·5	34·5	18	28·5	12·5	12·5	6	1	216

TABLE XXVII. Diagonal conjugate.

Inter-cristal.	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—
20·75—	—	—	1	—	—	—	—	—	—	—	—	—
21·25—	—	—	—	—	—	—	—	—	—	—	—	—
21·75—	—	1	—	1	—	1	—	—	—	—	—	—
22·25—	—	—	—	—	—	—	—	—	—	—	—	—
22·75—	—	1	—	1	—	2	2	2	—	—	—	—
23·25—	—	—	—	—	1·25	0·25	—	—	1·5	—	—	—
23·75—	—	—	—	2	6·25	3·25	2·5	1	1·5	—	—	—
24·25—	1	1	1	0·5	6	1	2	2	1	1	—	—
24·75—	—	1	1	4·5	5·5	8·5	2	2	5	—	—	1
25·25—	—	1	0·5	4	4	3·5	7·5	2	1	—	1	—
25·75—	—	1	1·5	6	7	4·5	6	4·5	2·5	1·5	—	—
26·25—	1	—	1	0·5	4	5	2	3	1	0·5	—	—
26·75—	—	—	—	4·5	3·5	4	5·5	6	2	1	2	—
27·25—	—	—	—	—	2	3	3	1	1	1	0·5	1
27·75—	—	—	—	—	1	4	3	2	2	—	0·5	—
28·25—	—	—	—	2	—	1	—	2	1	—	—	—
28·75—	—	—	—	—	—	—	—	—	—	—	1	—
Totals	2	6	6	26	40·5	41	35·5	27·5	19·5	5	5	2

TABLE XXVIII. Antero-posterior.

Totals	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—
1	—	—	0·5	0·5	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	2	1	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—
8	—	1	1	2	2	2	—	—	—	—	—	—
3	—	—	—	—	0·5	1	1·5	—	—	—	—	—
16·5	—	—	1	4·5	0·5	3·5	3	1	2	1	—	—
16·5	—	—	1	2·5	5·5	3	3·25	0·25	1	—	—	—
30·5	—	—	1	0·5	7·5	8	5·25	8·25	—	—	—	—
24·5	—	—	1	4	5·75	2·75	6	3	1	1	—	—
34·5	—	1	0·5	6	10·75	5·25	4	4·5	1	—	1	0·5
18	—	—	—	1	4	4·25	6·25	1	1	—	—	0·5
28·5	1	—	1	2·5	6·5	5·25	6·25	3·5	2·5	—	—	—
12·5	—	—	—	—	1	2	1	3	3	2	0·5	—
12·5	—	—	—	1	2	1	—	4	3	1·5	—	—
6	—	—	—	—	1	1	3	—	1	—	—	—
1	—	—	—	—	—	—	—	—	1	—	—	—
216	1	2	7	24·5	49	40	39·5	28·5	16·5	5·5	1·5	1

TABLE XXIX. Inter-tuberal.

Inter-cristal.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—
20·75—	—	1	—	—	—	—	—	—	—	—	—
21·25—	—	—	—	—	—	—	—	—	—	—	—
21·75—	—	—	2	—	—	1	—	—	—	—	—
22·25—	—	—	—	—	—	—	—	—	—	—	—
22·75—	1	1	2	1	1	1	1	—	—	—	—
23·25—	—	—	0·5	—	1·5	1	—	—	—	—	—
23·75—	—	4	1·5	0·5	5·5	2	3	—	—	—	—
24·25—	1	2	1	7	3·5	2	—	—	—	—	—
24·75—	—	—	5	6·5	9·5	4	4·5	1	—	—	—
25·25—	—	2	7·5	3	4	4·5	2·5	1	—	—	—
25·75—	2	4	6·5	5	6	9	1	—	0·5	0·25	0·25
26·25—	—	3	2	2·5	3·5	2·5	3	0·5	0·5	0·25	0·25
26·75—	4	2	4·5	3·5	7·5	3·5	1	2	0·5	—	—
27·25—	—	1·25	2·75	—	3	3·5	1	1	—	—	—
27·75—	—	0·25	1·25	2	4	2	1	1	—	1	—
28·25—	1	—	1	2	1	—	1	—	—	—	—
28·75—	—	—	—	—	—	1	—	—	—	—	—
Totals	9	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5

TABLE XXX. Posterior sagittal.

Totals	5·75—	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—
1	—	—	1	—	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	1	1	1	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—	—	—
8	2	—	2	3	—	1	—	—	—	—	—	—
3	—	—	—	—	2	1	—	—	—	—	—	—
16·5	—	2·5	4	3	3	1	2	1	—	—	—	—
16·5	1	3·5	5·5	2·5	3	—	1	—	—	—	—	—
30·5	—	3	7·5	10	3	4	1	2	—	—	—	—
24·5	1·5	2	4	7·5	3·5	3	2	—	—	—	—	1
34·5	0·5	10·5	8	7·25	6·25	1	—	1	—	—	—	—
18	—	1·5	6	1·75	6·75	2	—	—	—	—	—	—
28·5	1	3·5	6	8·5	5	2·5	2	—	—	—	—	—
12·5	—	0·5	—	3	4·25	1·75	2	—	—	1	—	—
12·5	—	1	2	2·5	2·75	3·25	1	—	—	—	—	—
6	—	1	—	2	3	—	—	—	—	—	—	—
1	—	—	—	1	—	—	—	—	—	—	—	—
216	6	29	47	53	43·5	20·5	11	4	0	1	0	1

TABLE XXXI. Antero-posterior.

Diagonal conjugate.	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
8·75—														1
9·25—							1							2
9·75—							1							7
10·25—				1										24·5
10·75—				1										49
11·25—				1										40
11·75—				1										39·5
12·25—				1										28·5
12·75—														16·5
13·25—														5·5
13·75—														1·5
14·25—														·1
14·75—														
Totals	1	2	7	24·5	49	40	39·5	28·5	16·5	5·5	1·5	·1		216

TABLE XXXII. Inter-tuberal.

Diagonal conjugate.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
7·75—			2			3	1					6
8·25—		1	1	3	1							6
8·75—		2	1		2							6
9·25—		4	4	4	5	3	2	1				26
9·75—		5	7	6	9·5	8	5			0·5	0·5	40·5
10·25—	1	5	6·5	7	7·5	5	5	2		1		41
10·75—			6·5	4	10	5	5	2				35·5
11·25—			3	3	7	3	4					27·5
11·75—					2	2						19·5
12·25—						1						5
12·75—												5
13·25—												2
Totals	1	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5	216

TABLE XXXIII. Posterior sagittal.

Diagonal conjugate.	6·75—	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	Totals
9·25—	—	—	—	—	2	—	—	—	—	—	—	—	2
9·75—	—	2	2	1	—	1	—	—	—	—	—	—	6
10·25—	1	1	2	—	2	—	—	—	—	—	—	—	6
10·75—	1	7·5	4·5	5	3	3	1	1	—	—	—	—	26
11·25—	1	5·5	11·5	10	5·5	3	2	1	—	1	—	—	40·5
11·75—	2	5	13	11	7	2	—	1	—	—	—	—	41
12·25—	1	4	4	11	6·5	5	2	1	—	—	—	1	35·5
12·75—	—	3	3·5	9	9	2	1	—	—	—	—	—	27·5
13·25—	—	1	5·5	3	5	3	2	—	—	—	—	—	19·5
13·75—	—	—	—	1	2	—	2	—	—	—	—	—	5
14·25—	—	—	1	2	0·5	0·5	1	—	—	—	—	—	5
14·75—	—	—	—	—	1	1	—	—	—	—	—	—	2
Totals	6	29	47	53	43·5	20·5	11	4	0	1	0	1	216

TABLE XXXIV. Inter-tuberal.

Ant.tero-posterior.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
8·75—	—	—	—	—	1	—	—	—	—	—	—	1
9·25—	—	1	—	—	1	—	—	—	—	—	—	2
9·75—	—	2·5	1·5	2	1	—	—	—	—	—	—	7
10·25—	1	3·5	5·5	6	6	2	—	0·5	—	—	—	24·5
10·75—	2	3	11	6	16	6·5	2	2·5	—	—	—	49
11·25—	2	3	9	4	11	5·5	4	1·25	0·25	—	—	40
11·75—	2	7	6	6·5	6	6·5	4	0·25	1·25	—	—	39·5
12·25—	2	—	3	6·5	4·5	7·5	5	—	—	—	—	28·5
12·75—	—	—	1	2	2·5	8	1	1	—	1	—	16·5
13·25—	—	0·5	0·5	—	0·5	1	2	1	—	—	—	5·5
13·75—	—	—	—	—	0·5	—	1	—	—	—	—	1·5
14·25—	—	—	—	—	—	—	—	—	—	0·5	0·5	1
Totals	9	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5	216

TABLE XXXV. Posterior sagittal.

5·75—	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—
—	—	—	1	—	—	—	—	—	—	—	—
—	1	1	—	—	—	—	—	—	—	—	—
2	1	3	0·5	—	0·5	—	—	—	—	—	—
3	6	8·5	4·5	2	0·5	—	—	—	—	—	—
1	13	13·5	12	5	3·5	1	—	—	—	—	—
—	3	10·5	11·5	10	3	1	1	—	—	—	—
—	2	7·5	9·5	14·5	3·5	1·5	1	—	—	—	—
—	2	3	9·5	4·5	6	2·5	1	—	—	—	—
—	—	—	4·5	6	3	3	—	—	—	—	—
—	1	—	—	0·5	0·5	2	—	—	0·5	—	1
—	—	—	—	—	—	—	—	—	0·5	—	—
—	—	—	—	1	—	—	—	—	—	—	—

Totals
1
2
7
24·5
49
40
39·5
28·5
16·5
5·5
1·5
1

Totals	6	29	47	53	43·5	20·5	11	4	0	1	0	1

TABLE XXXVI. Inter-tuberal.

Posterior sagittal.	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
5·75—	1	1	1	—	1	2	—	—	—	—	—	6
6·25—	1	6	8·5	2·5	5	5	1	—	—	—	—	29
6·75—	3	9	4·5	11·5	13	2	2	2	—	—	—	47
7·25—	2	3	12·5	6·5	13	9	5	1·5	0·5	—	—	53
7·75—	1	1·25	9·75	6·5	11	9	3	—	1	0·5	0·5	43·5
8·25—	1	0·25	1·25	6	3	4	3	1	—	1	—	20·5
8·75—	—	—	—	—	2	6	1	2	—	—	—	11
9·25—	—	—	—	—	1	—	3	—	—	—	—	4
9·75—	—	—	—	—	—	—	—	—	—	—	—	0
10·25—	—	—	—	—	1	—	—	—	—	—	—	1
10·75—	—	—	—	—	—	—	—	—	—	—	—	0
11·25—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	9	20·5	37·5	33	50	37	19	6·5	1·5	1·5	0·5	216

APPENDIX III.

APPENDIX III.

CORRELATION TABLES OF THE DIAMETERS WITH THE BONE MEASUREMENTS.

TABLE XXXVII. Obstetric conjugate.

Right hip—height.

	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	Totals
15·75—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	3
17·25—	—	—	1	4	—	—	—	1	—	—	—	—	—	—	6
17·75—	1	1	1	5	3	3·5	6·5	2	—	—	—	—	—	—	23
18·25—	0·5	2·5	—	10	7	6	3·5	8	0·5	1	—	—	—	—	39
18·75—	—	—	2	5	5	13·5	5·5	7	4·5	1·5	—	—	—	—	44
19·25—	—	—	—	3	5	5	5·5	2·5	2	3	—	—	—	—	26
19·75—	—	—	—	1	3	8	6	9	6	5	—	2	—	—	40
20·25—	—	—	—	0·5	1·5	1	3	4·5	2·5	2	2	1	—	—	18
20·75—	—	—	—	—	—	2	—	3	2·5	0·5	—	1	—	—	9
21·25—	—	—	—	—	—	1	1	1	—	1	—	—	—	—	4
21·75—	—	—	—	—	—	—	1	—	—	1	—	—	—	1	3
Totals	1·5	3·5	7	29·5	24·5	40	32	38	18	15	2	4	0	1	216

TABLE XXXVIII. Transverse.

	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—
15·75—	1	—	—	—	—	—	—	—	—
16·25—	—	—	—	—	—	—	—	—	—
16·75—	—	—	—	1	1	1	—	—	—
17·25—	—	—	2	3	—	1	—	—	—
17·75—	—	—	1	7	4	6	3	1·5	0·5
18·25—	—	—	1·5	8·5	7	17	4	1	—
18·75—	1	—	1	4·5	8	20	6	3	0·5
19·25—	—	1	—	3	2	7·5	7·5	4	1
19·75—	—	—	1	1	7·5	17	7·5	5	1
20·25—	—	—	—	—	—	5·5	6·5	5	1
20·75—	—	—	—	—	—	3	2	3	1
21·25—	—	—	—	—	—	—	—	2	2
21·75—	—	—	—	1	—	1	1	—	—
Totals	2	1	6·5	29	29·5	79	37·5	24·5	7

TABLE XXXIX. Diagonal conjugate.

Right hip—height.

	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
15·75—	—	—	1	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	1	1	1	—	—	—	—	—	—	—	—	3
17·25—	—	1	—	3	1	1	—	—	—	—	—	—	6
17·75—	1	2	2	2	8	2	4	2	—	—	—	—	23
18·25—	1	2	2	8	12·5	7·5	4	1	1	—	—	—	39
18·75—	—	—	—	8	10	10	6	6·5	3·5	—	—	—	44
19·25—	—	—	—	1	6	8·5	4·5	4	2	—	—	—	26
19·75—	—	—	—	3	2	8	7	9	7	2	2	—	40
20·25—	—	—	—	—	1	3	4	4	3	1	1	1	18
20·75—	—	—	—	—	—	1	3	1	2	2	—	—	9
21·25—	—	—	—	—	—	—	2	—	1	—	1	—	4
21·75—	—	—	—	—	—	—	1	—	—	—	1	1	3
Totals	2	6	6	26	40·5	41	35·5	27·5	19·5	5	5	2	216

TABLE XL. Inter-cristal.

Right hip—height.	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	27·25—	27·75—	28·25—	28·75—	Totals
15·75—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	—	1	—	—	1	1	—	—	—	—	—	—	—	—	3
17·25—	—	—	1	—	1	—	2	—	2	—	—	—	—	—	—	—	—	6
17·75—	—	—	—	—	2	—	5	5	2·5	1·5	3·5	0·5	1	1	—	1	—	23
18·25—	—	—	1	—	1	1·5	5·5	4	9·5	6	5·5	3	1	1	—	—	—	39
18·75—	—	—	—	—	2	1	2·5	3·5	5·5	4	11·5	6·5	6	0·5	1	—	—	44
19·25—	—	—	1	—	1	—	—	1	3	5·5	2·5	2	7	2	1	—	—	26
19·75—	—	—	—	—	—	—	1	1	3	7	7	3	9	2	5	2	—	40
20·25—	—	—	—	—	—	—	—	1	3	—	2·5	2·5	3·5	1·5	3	1	—	18
20·75—	—	—	—	—	—	0·5	0·5	—	1	0·5	2	0·5	1	2	—	1	—	9
21·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	1	4
21·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	2·5	0·5	—	—	3
Totals	1	0	3	0	8	3	16·5	16·5	30·5	24·5	34·5	18	28·5	12·5	12·5	6	1	216

TABLE XLI. Inter-spinous.

Right hip—height.	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	Totals
15·75—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	—	1	—	—	—	0·5	0·5	—	—	—	1	—	—	—	—	—	—	—	3
17·25—	—	—	—	—	2	—	—	—	2	1	—	—	1	—	—	—	—	—	—	—	—	6
17·75—	—	—	—	—	—	—	1	2·5	4·5	—	7	2	1	1	1	1	1	—	—	—	—	23
18·25—	0·5	0·5	—	—	—	2	4	—	2	2·5	6·5	9	6	3	1	1·5	0·5	—	—	—	—	39
18·75—	—	—	—	—	—	2	1	2	1	4	9·5	2·5	5·5	6·5	5	4	—	1	—	—	—	44
19·25—	—	—	—	—	—	—	2	3	—	2	4	0·5	3	3·5	6	—	1	1	—	—	—	26
19·75—	—	—	—	—	—	—	—	1	2	2	7	2	5	6·5	5·5	3·5	2·5	2	—	1	—	40
20·25—	—	—	—	—	—	—	—	1	—	2	2	0·5	1·5	1	6	1	0·5	0·5	1	—	1	18
20·75—	—	—	—	—	—	—	—	0·5	0·5	1	—	—	1	—	4	—	—	1	0·5	0·5	—	9
21·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	3	—	—	—	—	4
21·75—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	1	—	—	—	—	3
Totals	1·5	0·5	0	0	3	4	8	10	13·5	15	36	16·5	24	23·5	28·5	12	9·5	6·5	1·5	1·5	1	216

TABLE XLII. Obstetric conjugate.

TABLE XLIII. Transverse.

TABLE XLII. Obstetric conjugate.

Left hip—height.	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	Totals
15·25—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
15·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	2
17·25—	—	—	3	4	—	—	—	—	—	—	—	—	—	—	7
17·75—	1	1	—	5	2	3·5	4·5	2	—	—	—	—	—	—	19
18·25—	0·5	1·5	2	3	6	13·5	7·5	6	3	1	—	—	—	—	44
18·75—	—	—	—	4	4	6	5·5	4·5	3·5	3·5	—	—	—	—	31
19·25—	—	—	—	1	4	7	5	5	3	3	—	1	—	—	29
19·75—	—	—	—	0·5	1·5	2	3	8	5·5	4·5	2	2	—	—	29
20·25—	—	—	—	—	—	1	2	2·5	2·5	—	—	—	—	—	8
20·75—	—	—	—	—	—	1	1	2	—	2	—	1	—	—	7
21·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0
21·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
22·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals	1·5	3·5	7	29·5	24·5	40	32	38	18	15	2	4	0	1	216

TABLE XLIII. Transverse.

Left hip—height.	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	Totals
15·25—	1	—	—	—	—	—	—	—	—	1
15·75—	—	—	—	—	—	—	—	—	—	0
16·25—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	1	—	1	—	—	—	2
17·25—	—	—	—	3	1	2	—	—	—	7
17·75—	—	—	1	2	1	5	—	—	—	19
18·25—	1	2·5	—	7·5	6	16	2·5	2·5	0·5	38
18·75—	—	1	—	4·5	6	19	9	4	0·5	44
19·25—	—	—	—	3	4·5	11	6·5	4	1	31
19·75—	—	—	—	2	4·5	12	6·5	3	—	29
20·25—	—	—	—	—	2·5	10	8·5	5	3	29
20·75—	—	—	—	—	—	1	2	3	1	8
21·25—	—	—	—	—	—	2	1	3	1	7
21·75—	—	—	—	1	—	—	—	—	—	0
22·25—	—	—	—	—	—	—	—	—	—	1
Totals	2	1	6·5	29	29·5	79	37·5	24·5	7	216

TABLE XLIV. Diagonal conjugate.

Left hip—height.	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	Totals
15·25—	—	—	1	—	—	—	—	—	—	—	—	—	1
15·75—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	1	—	—	—	—	—	—	—	—	2
17·25—	—	3	—	3	1	—	—	—	—	—	—	—	7
17·75—	1	2	—	3	6	3	2	2	—	—	—	—	19
18·25—	—	—	4	7	13·5	5·5	5	2	1	—	—	—	38
18·75—	1	1	—	7	10	13	7	3	2	—	—	—	44
19·25—	—	—	—	2	7	8·5	3·5	5·5	4·5	—	—	—	31
19·75—	—	—	—	3	2	6	8	4	3	2	1	—	29
20·25—	—	—	—	—	1	4	3	10	7	1	2	1	29
20·75—	—	—	—	—	—	1	4	1	1	1	—	—	8
21·25—	—	—	—	—	—	—	3	—	1	1	2	—	7
21·75—	—	—	—	—	—	—	—	—	—	—	—	1	0
22·25—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals	2	6	6	26	40·5	41	35·5	27·5	19·5	5	5	2	216

TABLE XLV. Inter-cristal.

Left hip—height.	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	27·25—	27·75—	28·25—	28·75—	Totals
15·25—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
15·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	2
17·25—	—	—	1	—	2	—	1	1	2	—	—	—	—	—	—	—	—	7
17·75—	—	—	—	—	2	—	4	4	2·5	3·5	1	—	1	—	—	1	—	19
18·25—	—	—	1	—	1	1·5	8	4·5	6	3·5	7	2·5	2	1	—	—	—	38
18·75—	—	—	—	—	2	—	1	2	9	5·5	10·5	6·5	5	1·5	1	—	—	44
19·25—	—	—	—	—	1	1	1	2	4	2·5	4·5	3	8	2	2	—	—	31
19·75—	—	—	1	—	—	—	1	1	2	8	4	3	5	1	1	2	—	29
20·25—	—	—	—	—	—	0·5	0·5	1	3	1	6·5	2·5	6	3	4	1	—	29
20·75—	—	—	—	—	—	—	—	—	1	0·5	0·5	—	0·5	1·5	3	1	—	8
21·25—	—	—	—	—	—	—	—	—	—	—	0·5	0·5	1	1·5	1·5	1	1	7
21·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
22·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Totals	1	0	3	0	8	3	16·5	16·5	30·5	24·5	34·5	18	28·5	12·5	12·5	6	1	216

TABLE XLVI. Inter-spinous.

Left hip—height.	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	22·75—	23·25—	23·75—	24·25—	24·75—	25·25—	25·75—	26·25—	26·75—	Totals
15·25—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
15·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	2
17·25—	—	—	—	—	1	—	—	—	2·5	1·5	1	—	1	—	—	—	—	—	—	—	—	7
17·75—	—	—	—	—	1	1	1	0·5	2·5	1	5	2	1	1	1	1	1	—	—	—	—	19
18·25—	0·5	0·5	—	—	—	2	4	2	4	1·5	6·5	7	5	1	1	2·5	0·5	—	—	—	—	38
18·75—	—	—	—	—	—	1	1	2	1	3	8·5	4·5	7·5	8	2·5	3	—	2	—	—	—	44
19·25—	—	—	—	—	—	—	1	2	—	4	6	0·5	2	3	10	0·5	1	1	—	—	—	31
19·75—	—	—	—	—	—	—	1	2	2	—	5	2	4	6·5	1·5	1·5	2·5	1	—	—	—	29
20·25—	—	—	—	—	—	—	—	1·5	0·5	3	4	0·5	2·5	2	8·5	2·5	—	1	1	1	1	29
20·75—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	3	—	1·5	1·5	0·5	0·5	—	8
21·25—	—	—	—	—	—	—	—	—	1	—	—	—	1	1	1	1	2	—	—	—	—	7
21·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
22·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	1·5	0·5	0	0	3	4	8	10	13·5	15	36	16·5	24	23·5	28·5	12	9·5	6·5	1·5	1·5	1	216

TABLE XLVII. Right hip—breadth.

TABLE XLVIII. Left hip—breadth.

TABLE XLVII. Right hip—breadth.

Obstetric conjugate.	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—	Totals
7·25—	—	—	—	—	1	0·5	—	—	—	—	—	—	1·5
7·75—	—	—	—	—	1	0·5	2	—	—	—	—	—	3·5
8·25—	1	—	—	3	1	1	1	—	—	—	—	—	7
8·75—	—	—	—	3·5	8	10·5	5	2·5	—	—	—	—	29·5
9·25—	—	—	—	1	5	8	3	5·5	1	1	—	—	24·5
9·75—	—	—	—	1·5	4·5	11	6	9	6	1	1	—	40
10·25—	—	—	—	1·5	2·5	5	7	6·5	6·5	2	1	—	32
10·75—	—	1	—	—	3	9	10	5·5	7·5	1	1	—	38
11·25—	—	—	—	—	—	3·5	5·5	2	4	3	—	—	18
11·75—	—	—	—	—	—	2·5	3	3	2·5	3	—	1	15
12·25—	—	—	—	—	—	—	—	—	—	2	—	—	2
12·75—	—	—	—	—	—	—	1	2	1	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	—	—	—	1	—	1
Totals	1	1	0	10·5	26	51·5	43·5	36	28·5	13	4	1	216

TABLE XLVIII. Left hip—breadth.

Obstetric conjugate.	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—	Totals
7·25—	—	—	—	—	—	1	0·5	—	—	—	—	—	—	1·5
7·75—	—	—	—	—	—	1	1·5	1	—	—	—	—	—	3·5
8·25—	1	—	—	0·5	2·5	1	2	—	—	—	—	—	—	7
8·75—	—	—	—	—	3	10·5	6·5	8	1	0·5	—	—	—	29·5
9·25—	—	—	—	—	—	5	7	6	4	2·5	—	—	—	24·5
9·75—	—	—	—	—	2·5	5	8·5	9·5	8·5	3·5	2·5	—	—	40
10·25—	—	—	—	—	2·5	0·5	6	7	8	5	3	—	—	32
10·75—	—	—	—	—	1	2	6	14	6	8	1	—	—	38
11·25—	—	—	—	—	—	0·5	2	4·5	4	6	1	—	—	18
11·75—	—	—	—	—	—	1·5	1	5	3	0·5	3	—	1	15
12·25—	—	—	—	—	—	—	—	—	—	—	2	—	—	2
12·75—	—	—	—	—	—	—	—	—	3	1	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Totals	1	0	0	0·5	11·5	28	41	55	37·5	27	12·5	1	1	216

TABLE XLIX. Sacrum—height.

Obstetric conjugate.	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
7·25—	—	—	—	—	—	—	1·5	—	—	—	—	—	—	—	1·5
7·75—	—	—	—	1	—	1	0·5	1	—	—	—	—	—	—	3·5
8·25—	—	0·5	1	1·5	—	2	—	1	—	—	—	1	—	—	7
8·75—	—	—	—	—	4	5	9	5	1·5	2	1	2	—	—	29·5
9·25—	—	—	—	4	1	3	2	5	5·5	3	—	—	—	—	24·5
9·75—	—	—	1	2	3	5	9	6·5	4·5	3	2·5	1	1	1·5	40
10·25—	—	—	1	2	0·5	4	7	6	3·5	4	3·5	—	—	0·5	32
10·75—	1	—	—	2	1·5	2	3·5	8	5·5	8	4·5	2	—	—	38
11·25—	—	—	—	—	—	1	1·5	7·5	2	3·5	2·5	—	—	—	18
11·75—	—	—	1	—	1	—	—	2·5	1	5	1·5	2	1	—	15
12·25—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	2
12·75—	—	—	—	—	—	—	1	1	—	1	1	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

TABLE L. Sacrum—breadth.

Obstetric conjugate.	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	Totals
7·25—	—	—	—	—	—	1·5	—	—	—	—	1·5
7·75—	—	—	—	1	2	0·5	—	—	—	—	3·5
8·25—	1	—	—	3	2	1	—	—	—	—	7
8·75—	—	—	3	3	14	4	5	0·5	—	—	29·5
9·25—	—	—	0·5	5·5	7	5	6	0·5	—	—	24·5
9·75—	—	—	—	3	11·5	15	3·5	7	—	—	40
10·25—	—	—	—	1·5	5·5	14·5	7	2·5	—	1	32
10·75—	—	—	—	5·5	3	10·5	10·5	8·5	—	—	38
11·25—	—	—	—	—	2·5	6	4	4·5	1	—	18
11·75—	—	—	—	3	1·5	5·5	4	1	—	—	15
12·25—	—	—	—	—	—	—	—	2	—	—	2
12·75—	—	—	—	1	—	—	3	—	—	—	4
13·25—	—	—	—	—	—	—	—	—	—	—	0
13·75—	—	—	—	—	—	—	—	1	—	—	1
Totals	1	0	3·5	26·5	49	63·5	43	27·5	1	1	216

TABLE LI. Right hip—breadth.

Transverse.	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—	Totals
10·25—	1	—	—	—	—	1	—	—	—	—	—	—	2
10·75—	—	—	—	—	—	—	1	—	—	—	—	—	1
11·25—	—	—	—	0·5	2·5	2	0·5	1	—	—	—	—	6·5
11·75—	—	1	—	5	7·5	6	5·5	2	1	—	1	—	29
12·25—	—	—	—	1	4	9·5	7	3·5	3	1·5	—	—	29·5
12·75—	—	—	—	3	12	21	13	15·5	7·5	5	2	—	79
13·25—	—	—	—	—	—	9	11·5	6·5	7	3·5	—	—	37·5
13·75—	—	—	—	1	—	3	4·5	7	5	2	1	1	24·5
14·25—	—	—	—	—	—	—	0·5	0·5	5	1	—	—	7
Totals	1	1	0	10·5	26	51·5	43·5	36	28·5	13	4	1	216

TABLE LII. Left hip—breadth.

	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—
10·25—	1	—	—	—	—	—	1	—	—	—	—	—	—
10·75—	—	—	—	—	—	—	—	1	—	—	—	—	—
11·25—	—	—	—	—	1	2	2	0·5	1	—	—	—	—
11·75—	—	—	—	0·5	5·5	5	8·5	7·5	—	1	—	1	—
12·25—	—	—	—	—	1	5·5	5	11·5	3·5	2·5	0·5	—	—
12·75—	—	—	—	—	4	13	15·5	17·5	17	6·5	5·5	—	—
13·25—	—	—	—	—	—	0·25	7·75	10	10·5	7	2	—	—
13·75—	—	—	—	—	—	2·25	1·25	6·5	3·5	6·5	3·5	—	1
14·25—	—	—	—	—	—	—	—	0·5	2	3·5	1	—	—
Totals	1	0	0	0·5	11·5	28	41	55	37·5	27	12·5	1	1

TABLE LIII. Sacrum—height.

Transverse.	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
10·25—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	2
10·75—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
11·25—	—	—	—	2	1	—	1	—	0·5	1	1	—	—	—	6·5
11·75—	—	—	0·5	1·5	2	6	4	8·5	1·5	4	—	1	—	—	29
12·25—	—	0·5	1·5	1·5	1	4	6·5	6·5	3	4	1	—	—	—	29·5
12·75—	1	—	—	4·5	2·5	7	17	22·5	5·5	9	5	3	1	1	79
13·25—	—	—	1	1	4·5	1	3·5	4·75	7·75	7	4	1	2	—	37·5
13·75—	—	—	1	1	—	4	3	1·25	4·25	3·5	3·5	2	—	1	24·5
14·25—	—	—	—	—	—	1	1	1	—	2	1	1	—	—	7
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

TABLE LIV. Sacrum—breadth.

	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—
10·25—	1	—	—	—	—	—	1	—	—	—
10·75—	—	—	0·5	0·5	—	—	—	—	—	—
11·25—	—	—	1	3·5	2	—	—	—	—	—
11·75—	—	—	2	10	6	7	3	1	—	—
12·25—	—	—	—	4·5	11	8·75	4·25	1	—	—
12·75—	—	—	—	7	22·5	27·75	16	4·75	1	—
13·25—	—	—	—	1	4	14	7·75	10·75	—	—
13·75—	—	—	—	—	3·5	3	9	9	—	—
14·25—	—	—	—	—	—	3	2	1	—	1
Totals	1	0	3·5	26·5	49	63·5	43	27·5	1	1

APPENDIX IV.

CORRELATION TABLES OF THE BONE MEASUREMENTS WITH ONE ANOTHER

APPENDIX IV.

CORRELATION TABLES OF THE BONE MEASUREMENTS WITH ONE ANOTHER.

TABLE LV. Right hip—breadth.

Right hip—height.

	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—	Totals
15·75—	1	—	—	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	2	1	—	—	—	—	—	—	—	3
17·25—	—	—	—	3·5	2·5	—	—	—	—	—	—	—	6
17·75—	—	1	—	3	8	6	4	—	1	—	—	—	23
18·25—	—	—	—	—	8·5	16·5	11	3	—	—	—	—	39
18·75—	—	—	—	—	4	18	10·5	9·5	2	—	—	—	44
19·25—	—	—	—	2	2	8	6	6	2	—	—	—	26
19·75—	—	—	—	—	—	3	10	10	12	5	—	—	40
20·25—	—	—	—	—	—	—	1	5	4	7	1	—	18
20·75—	—	—	—	—	—	—	1	2·5	5·5	—	—	—	9
21·25—	—	—	—	—	—	—	—	—	1	1	1	1	4
21·75—	—	—	—	—	—	—	—	—	1	—	2	—	3
Totals	1	1	0	10·5	26	51·5	43·5	36	28·5	13	4	1	216

TABLE LVI. Left hip—breadth.

	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—
15·75—	1	—	—	—	—	—	—	—	—	—	—	—	—
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—
16·75—	—	—	—	—	2	1	—	—	—	—	—	—	—
17·25—	—	—	—	0·5	2·5	3	—	—	—	—	—	—	—
17·75—	—	—	—	—	5	8	5	3	2	—	—	—	—
18·25—	—	—	—	—	1	5·5	16·5	14	2	—	—	—	—
18·75—	—	—	—	—	—	7·5	11·5	17	7	1	—	—	—
19·25—	—	—	—	—	1	3	6	9	6	1	—	—	—
19·75—	—	—	—	—	—	—	2	10	14	11	3	—	—
20·25—	—	—	—	—	—	—	—	1	3	8	6	—	—
20·75—	—	—	—	—	—	—	—	1	2·5	5	0·5	—	—
21·25—	—	—	—	—	—	—	—	—	—	1	2	—	1
21·75—	—	—	—	—	—	—	—	—	1	—	1	1	—
Totals	1	0	0	0·5	11·5	28	41	55	37·5	27	12·5	1	1

TABLE LVII. Left hip—height.

Right hip—height.

	15·25—	15·75—	16·25—	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	Totals
15·75—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	3
17·25—	—	—	—	—	5	1	—	—	—	—	—	—	—	—	—	6
17·75—	—	—	—	—	1	14	7	1	—	—	—	—	—	—	—	23
18·25—	—	—	—	—	—	4	28	7	—	—	—	—	—	—	—	39
18·75—	—	—	—	—	—	—	3	34	6	1	—	—	—	—	—	44
19·25—	—	—	—	—	—	—	—	2	21	3	—	—	—	—	—	26
19·75—	—	—	—	—	—	—	—	—	4	25	10	1	—	—	—	40
20·25—	—	—	—	—	—	—	—	—	—	—	16	2	—	—	—	18
20·75—	—	—	—	—	—	—	—	—	—	—	3	4	2	—	—	9
21·25—	—	—	—	—	—	—	—	—	—	—	—	1	3	—	—	4
21·75—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	1	3
Totals	1	0	0	2	7	19	38	44	31	29	29	8	7	0	1	216

TABLE LVIII. Sacrum—breadth.

	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—
15·75—	1	—	—	—	—	—	—	—	—	—
16·25—	—	—	—	—	—	—	—	—	—	—
16·75—	—	—	—	1	2	—	—	—	—	—
17·25—	—	—	2	3	1	—	—	—	—	—
17·75—	—	—	—	4	10	7	2	—	—	—
18·25—	—	—	1	10	13	12	—	3	—	—
18·75—	—	—	—	4	15	11·5	11·5	2	—	—
19·25—	—	—	0·5	1·5	3	11	6	4	—	—
19·75—	—	—	—	2	4	13	15	6	—	—
20·25—	—	—	—	1	1	3	4·5	7·5	1	—
20·75—	—	—	—	—	—	3	3	3	—	—
21·25—	—	—	—	—	—	1	1	1	—	1
21·75—	—	—	—	—	—	2	—	1	—	—
Totals	1	0	3·5	26·5	49	63·5	43	27·5	1	1

TABLE LIX.

Sacrum—height.

Right hip—height.	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
15·75—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	0·5	0·5	—	—	1	—	1	—	—	—	—	—	—	3
17·25—	—	—	0·5	1·5	2	—	1	1	—	—	—	—	—	—	6
17·75—	—	—	—	1	—	8	5	5	1	1	2	—	—	—	23
18·25—	1	—	—	3	3	6	11	4	4	3	2	1	—	1	39
18·75—	—	—	—	2	3	4	7	11·5	4·5	6	4	2	—	—	44
19·25—	—	—	—	2	2	—	5	4	5	7	—	—	—	1	26
19·75—	—	—	2	2	1	2	5	9	6	4	4	3	2	—	40
20·25—	—	—	—	—	—	1	1	6	3	4	2	—	1	—	18
20·75—	—	—	1	—	—	1	—	2	—	2·5	1·5	1	—	—	9
21·25—	—	—	—	—	—	—	1	—	—	1	1	1	—	—	4
21·75—	—	—	—	—	—	—	—	1	—	2	—	—	—	—	3
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

TABLE LX.

Left hip—height.

Right hip—breadth.	15·25—	15·75—	16·25—	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	Totals
11·25—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
11·75—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
12·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
12·75—	—	—	—	1	4·5	2	1	1	1	—	—	—	—	—	—	10·5
13·25—	—	—	—	1	2·5	7	8·5	5	2	—	—	—	—	—	—	26
13·75—	—	—	—	—	—	6	15·5	15	10	5	—	—	—	—	—	51·5
14·25—	—	—	—	—	—	1	11	12·5	8	7	4	—	—	—	—	43·5
14·75—	—	—	—	—	—	1	2	8·5	7	7	7	2·5	1	—	—	36
15·25—	—	—	—	—	—	1	—	2	2	7	10	3·5	3	—	—	28·5
15·75—	—	—	—	—	—	—	—	—	1	3	7	2	—	—	—	13
16·25—	—	—	—	—	—	—	—	—	—	—	1	—	2	—	1	4
16·75—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
Totals	1	0	0	2	7	19	38	44	31	29	29	8	7	0	1	216

TABLE LXI. Left hip—breadth.

Right hip—breadth

	10·75—	11·25—	11·75—	12·25—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—	Totals
11·25—	1												1
11·75—													0
12·25—						1							1
12·75—				0·5	8·5								11·5
13·25—					3	17·75	1						28
13·75—						8·25	32·25	4·25					41
14·25—						0·5	2·5	35·5	9·5	1			55
14·75—							1	9·5	22	7·5	19·5	3·5	37·5
15·25—								1			3	10	27
15·75—												1	12·5
16·25—													1
16·75—													1
Totals	1	0	0	0·5	11·5	28	41	55	37·5	27	12·5	1	216

TABLE LXII. Sacrum—breadth.

	8·75	9·25	9·75	10·25	10·75	11·25	11·75	12·25	12·75	13·25	Totals
11·25—	1										1
11·75—				1							1
12·25—											0
12·75—											10·5
13·25—					4	2					26
13·75—				1·5	15·5	2					51·5
14·25—				5	16·5	19	6	2			43·5
14·75—				0·5	5·5	14	12	6·5			36
15·25—					5	11	10	7			28·5
15·75—					1	13·5	8	6			13
16·25—							4	4	1		4
16·75—							1	1			1
Totals	1	0	0	3·5	26·5	49	43	27·5	1	1	216

TABLE LXIII. Sacrum—height.

Right hip—breadth.

	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
11·25—				1											1
11·75—															1
12·25—															0
12·75—		0·5	1	0·5	1·5	2	3	1		1					10·5
13·25—				3	2·5	6·5	4	6	2		2				26
13·75—	1			4	1	3·5	12	13	4	9	3	1			51·5
14·25—			1	1	4	4	8	7·5	7·5	4·5	2	3			43·5
14·75—			1	2		4	6	6	3	7·5	4·5		1		36
15·25—			1		1	3	2	5	5	5·5	2	3	1		28·5
15·75—				1	1			4	1	2	3		1		13
16·25—							1	2		1					4
16·75—												1			1
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

TABLE LXIV. Left hip—breadth.

Left hip—height.	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	13·75—	14·25—	14·75—	15·25—	15·75—	16·25—	16·75—	17·25—	17·75—	18·25—	18·75—	19·25—	19·75—	20·25—	20·75—	21·25—	21·75—	22·25—	Totals
15·25—	1																								1
15·75—																									0
16·25—																									0
16·75—				1	3·5	3	7	1	—																2
17·25—				0·5	3	7	—	7	11·5	16	15														7
17·75—					3	6·5	5·5	11·5	13·5	1	1														19
18·25—					1	5·5	—	1	6	11	9														38
18·75—						1	4	6	11	7	7														44
19·25—							1	3	7	7	9														31
19·75—							—	—	—	5	7·5	11·5	5												29
20·25—							—	—	—	—	1	4·5	2·5												29
20·75—											2	2	2												8
21·25—											—	—	—												7
21·75—																									0
22·25—																									1
Totals	1	0	0	0·5	11·5	28	41	55	37·5	27	12·5	1	1	216											

Left hip—breadth. TABLE LXV. Sacrum—breadth.

Left hip—height.	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	Totals
15·25—	1										1
15·75—											0
16·25—											0
16·75—					1						2
17·25—				2	2						7
17·75—				1	6	6	1				19
18·25—					14	10	2				38
18·75—				1	15	14·5	8·5	3			44
19·25—				0·5	6	10	9	5			31
19·75—					4	11	8	3			29
20·25—					1	7	11·5	7·5	1		29
20·75—						2	1	4			8
21·25—						3	2	2			7
21·75—						—	—	1			0
22·25—						—	—	—			1
Totals	1	0	3·5	26·5	49	63·5	43	27·5	1	1	216

TABLE LXVI. Sacrum—height.

Left hip—height.	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
15·25—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
15·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·25—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
16·75—	—	0·5	1	0·5	2	1	1	1	—	—	—	—	—	—	2
17·25—	—	—	—	2	—	1	1	3	1	—	—	—	—	—	7
17·75—	—	—	—	—	—	6	5	4	2	1	—	—	—	—	19
18·25—	1	—	—	3	4	7	11	4	2	2	3	—	—	1	38
18·75—	—	—	—	1	2	3	7	11·5	5·5	8	4	2	—	—	44
19·25—	—	—	—	—	2	1	6	5	5	6	2	—	1	—	31
19·75—	—	—	—	1	4	2	4	7	5	2	2	2	—	—	29
20·25—	—	—	—	—	—	1	1	11	5	4	3	2	1	—	29
20·75—	—	—	—	—	—	1	—	—	—	4	2	—	2	—	8
21·25—	—	—	—	—	—	—	1	1	—	2·5	1·5	1	—	—	7
21·75—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
22·25—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

TABLE LXVII. Sacrum—height.

Left hip—breadth.

	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
10·75—				1											1
11·25—															0
11·75—															0
12·25—			0·25	0·25											0·5
12·75—		0·5	0·75	0·25	1	2	3	3							11·5
13·25—				3	2	6·5	4	6·25	1·25	3	1	2			28
13·75—				4	1	3·5	8	10·25	4·25	6	2	2			41
14·25—	1		1	2	5	5	13	8	7	8	4·5	2	1		55
14·75—			1	1	1	1	6	7	4	5·5	2·5	2·5	1		37·5
15·25—			0·5		1	2	1	6	6	5	4	0·5			27
15·75—			0·5	1			1	4	1	2	2		1		12·5
16·25—															1
16·75—															1
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

TABLE LXVIII. Sacrum—breadth.

	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	13·25—	Totals
10·75—	1										1
11·25—											0
11·75—											0
12·25—				0·5							0·5
12·75—				2·5	7	1					11·5
13·25—			1	6	16	4		1			28
13·75—			1	8	9	17	4	2			41
14·25—			0·5	6·5	10	15·5	15·5	7			55
14·75—					5	16	11·5	4			37·5
15·25—					3	8	7·5	9·5	1		27
15·75—				2		2	3·5	3	1		12·5
16·25—								1			1
16·75—							1				1
Totals	1	0	3·5	26·5	49	63·5	43	27·5	1	1	216

TABLE LXIX. Sacrum—height.

Sacrum—breadth.

	6·25—	6·75—	7·25—	7·75—	8·25—	8·75—	9·25—	9·75—	10·25—	10·75—	11·25—	11·75—	12·25—	12·75—	Totals
8·75—				1											1
9·25—															0
9·75—						1			0·5						3·5
10·25—			0·5	4·5	2	5	5		4·5	2					26·5
10·75—		0·5	0·5	2	3	7	11	13·5	1·5	4	4			1	49
11·25—			1	2	1	6	13·5	14	6	13	3	2	1	1	63·5
11·75—			2	2	2	4	5·5	10·5	4	4	4	5			43
12·25—				1	2		1	2·5	7	6·5	5·5		2		27·5
12·75—								1		1					1
13·25—															1
Totals	1	0·5	4	12·5	11	23	36	44·5	23·5	30·5	16·5	8	3	2	216

MISCELLANEA.

I. The Statistical Study of Dietaries.

By KARL PEARSON, F.R.S.

THERE is not the least doubt that a proper statistical study of diet would be of very great value. Such a study is of first class importance when we turn to the accurate discussion of working-class budgets. A statistical study of dietaries should consist of two parts. In the first section an analysis should be made of the food consumed and of the physiological value of its constituents for, say, a hundred working-class families, noting their income, occupation, rent, size of house and other details. In the next place an anthropometric, and where possible medical survey should be made of the families, their numbers, ages, statures, weights and general healths should be recorded, special pathological or disease conditions noted, and some record made of the habits of house-mother and father. Only when this has been fully, accurately and extensively enough done will it be possible to draw conclusions of real scientific value, and to give advice to the working-classes as to the best expenditure of income on foods.

A recent *Report upon a Study of the Diet of the Labouring Classes in the City of Glasgow* by Miss Dorothy E. Lindsay, issued by the authority of the Corporation and with a preface by Professor D. Noel Paton, M.D., has been widely reviewed, and various suggestions made therein have been cited as demonstrated facts without any critical examination of the data upon which they are based. Thus we have been told that a return to the national dish of porridge and milk is an urgent need of the Scottish working-classes, and Miss Lindsay's data have been cited as showing the inadequacy of the dietary of families with regular wages under 20*s.* per week. Miss Lindsay obtained dietaries of 60 working-class Glasgow families, and these dietaries show a very large amount of work and a considerable fulness of record. To the extent of 60 families she has certainly fulfilled the first requisite of an adequate enquiry as to the effectiveness of diet. Her families contained 400 individuals, of whom 246 were under 16 years of age. If we are to judge of the relative value of the various dietaries, this can only be done by discussing their effects on the 400 persons who partook of them. In order to obtain real knowledge from Miss Lindsay's results, this population ought to have been weighed and measured. Without this the dietaries seem to us of exceedingly small worth. Actually Miss Lindsay did ascertain the height and weight of a few children, put together in Appendix IV. as *Physical Condition of Children.*

This contains the heights of 10 girls and 7 boys, and the weights of 20 girls and 16 boys. These children are scattered over all ages from 5 to 13 and over the whole of the Groups A to L into which Miss Lindsay divides her families. If we only class her groups into three there is not even the weight of one boy and one girl for each year of age upon which to base any measure of the value of the dietaries! As an illustration of this let us take the important Group E of families with regular wages under 20*s.* Miss Lindsay, p. 18, provides the dietaries of five such

families containing 29 individuals, of whom 19 were children under 16. She writes of this Group: "In this section, which embraces those who may properly be called poor, not one diet reaches the minimum energy value of 3000 calories" (p. 18). Criticising individual diets she says: "In LI. the use of a greater proportion of the cheaper vegetable foods, e.g. potatoes and haricot beans, gave a better energy value for the same cost....In XXV. the animal protein is considerably in excess of the vegetable protein (see Appendix III.). As the former is more expensive, this diet could be improved and a higher protein content obtained by reversing the proportion of animal and vegetable protein. In view of the fact that the fat is low, necessarily so because of its cost, the carbohydrate intake should have been greater."

Dr Chalmers in his recent paper before the Royal Society of Medicine, "The House as a Contributory Factor in the Deathrate*," notes that Miss Lindsay's observations bear so directly on the inadequacy of the dietary of persons in the smaller houses that he quotes her sample dietaries in families with regular wages under 20*s.* per week and concludes with Miss Lindsay's remark that "the children are nearly all small and light in weight." It is not clear whether Miss Lindsay intended her remark to apply to Family XXV. only, or as Dr Chalmers supposes to the whole of Group E. Dr Chalmers' interpretation has been widely taken to be the true one although which is the correct interpretation matters little: *For of the individuals in this group not a single boy's weight is provided by Miss Lindsay, and of the girls in the group only two were measured.* These two are certainly below weight; they do not belong to Family XXV. but one to Family XVII. who shows developed rickets, and whose father has been a heavy drinker, and the other to Family LII. where the father suffers from phthisis and is in receipt of parish relief. It would therefore appear that Miss Lindsay's remark must apply to the group in general. But the whole demonstration of the effect of the dietaries is thus seen to turn on the weight of two individual girls aged 9 and 5 years respectively, one of whom has rickets†, and both of whom have degenerate fathers!

In order to test what relation, if any, the income of family has to weight of child, the correlation coefficients of weight (w) and income (i) for constant age have been found for both girls and boys for the whole of the 20 and 16 cases respectively provided by Miss Lindsay. We have‡:

Weight of Girls and Income for constant Age

$$_a r_{iw} = \cdot 03 \pm \cdot 15,$$

Weight of Boys and Income for constant Age

$$_a r_{iw} = \cdot 22 \pm \cdot 16.$$

In neither case is there any significance having regard to the probable error. Whether the weight of the child is or is not related to the parental income cannot possibly be settled on the data provided by Miss Lindsay, and, whether she possesses it or not, she publishes in her paper no material on which it would be possible to tell the effect of the dietaries of families with incomes under 20*s.* on the size and weight of the children.

But there are a great many other question-begging conclusions in Miss Lindsay's memoir. She starts apparently with the opinion that the physiological construction of the food is of no importance, and that a "calorie" whether obtained from peas or eggs, beans or beef is of equal value. But surely this is the very sort of question that an investigation of this kind should answer, not assume? Miss Lindsay criticises—at times severely—the housewife who spends her

* *Proceedings of the Royal Society of Medicine*, Vol. VI. (Section *Epidemiology and State Medicine*), pp. 155—181.

† Rickets can hardly be due to lowness of "calories" for some of the families with the highest calories (II. with 4003, and IV. with 3882) and high wages (IV. with 50*s.* 8*d.*, V. with 39*s.*, XXXIX. with 41*s.*) are rickety.

‡ I have most heartily to thank my colleague Miss Ethel M. Elderton for the values of most of the correlation coefficients of this note.

money on animal rather than on vegetable food, "Protein from vegetable sources is from one and a half to two times as much as that from animal sources. In one or two cases it is nearly three times as great, and in these diets the energy value received is remarkably high for the money laid out....In some of the studies this proportion of animal to vegetable protein is reversed....All these diets show the disadvantages of this large use of the animal food. The energy value is low and the cost is high. *How are these diets to be improved?* Study XIX. (Group G) seems to give the answer. In this family 'porridge was eaten twice a day.' The energy procured per penny spent was the second highest recorded, 619 calories, while it is noted that the children were strong, healthy and well-grown" (p. 28). And again :

"A porridge and milk diet contains the food principles in correct proportion. The protein-rich animal foods, flesh, fish, eggs, etc., are all too expensive for the labouring classes, and any increase in their amount in the diet is impracticable. But cheese and the cheap protein-rich vegetable foods, oatmeal, peas, beans, etc., should be more freely used" (p. 29). An examination of Study XIX. thus commended shows that 5·07 shillings were spent on animal, 8·75 shillings on vegetable food, or the expenditures were as 1 to 1·72, while in the population at large 698·77 shillings were spent on animal, 487·28 shillings on vegetable food, or the ratio was 1 to 0·72. This abnormal ratio is obtained in the family in question by taking no eggs, hardly any butter, and instead of milk, buttermilk, skimmilk and condensed milk; there is further no fish; the increased vegetable expenditure is on meal and potatoes. Now it would appear that before a statement is made that this is the right course to recommend, it is highly desirable to ascertain whether the money spent on vegetable or animal food is the more highly correlated with physical fitness in the individual. This can only be done with Miss Lindsay's material for the weights of the 20 girls and the 16 boys. Accordingly for these sparse data the correlations between A the expenditure per individual on animal food and V the expenditure per individual on vegetable food with weight of child for constant age were determined. These gave :

	Girls	Boys
a^r_{Aw}	... ·16 ± ·15	·07 ± ·17,
a^r_{Vw}	... ·07 ± ·15	·30 ± ·15.

If any stress could be laid on these results, we should have to conclude that money spent on animal food would be best in the case of girls, and money spent on vegetable food in the case of boys. But an examination of the probable errors shows that no weight whatever can be laid on the results. In fact that Miss Lindsay's data are wholly insufficient to answer the question of whether money spent on vegetable or animal food is the better. In fact if we take the correlation between weight w and F pence per individual spent on food we find :

	Girls	Boys
a^r_{Fw}	... ·15 ± ·15	·22 ± ·16,

both of which are low correlations and neither definitely significant having regard to their probable error.

Next the relation of weight in the children to the number of calories in animal food (C_A), the number of calories in vegetable food (C_V) and to the total number of calories in both (C_F) was investigated.

The following values were found :

	Girls	Boys
$a^r_{C_Aw}$	... ·16 ± ·15	·51 ± ·12,
$a^r_{C_Vw}$	... ·25 ± ·14	·30 ± ·15,
$a^r_{C_Fw}$	... ·20 ± ·14	·41 ± ·14.

If these results could be trusted at all, we should have to assert : (i) that the number of calories in the food is twice as influential in the case of the boy as in that of the girl, and

(ii) that the number of calories in the animal food is more influential than the number of calories in the vegetable food for the case of the boy, and the reverse is true for the case of the girl*. As a matter of fact the size of the probable errors shows us merely that it is very unsafe to draw any conclusions at all. On the basis of the scanty data provided by Miss Lindsay for the physical fitness of the individuals subjected to the various dietaries, no legitimate conclusions whatever can be drawn as to how wages or diet affect the individual; still less can it be asserted that a return to porridge and milk, and an avoidance of the purchase of flesh, fish and eggs would save the situation.

Indeed as far as any stress whatever can be laid on her slender material the conclusion to be drawn is entirely the other way, i.e. the greater the consumption of animal food relative to vegetable food the heavier will be the child. To test this the ratio of money spent on vegetable food (V) to the money spent on animal food (A) per individual was correlated with the weight of the child for constant age, i.e. the partial correlation ${}_a r_{w,\,V/A}$ was found. Further as the money spent on food might not have been spent to the best advantage the ratio of the number of calories in the vegetable food C_V to the number in the animal food C_A was also correlated with the weight for constant age, i.e. the partial correlation coefficient ${}_a r_{C_V/C_A,\,w}$ was found. The following values were determined:

		Girls	Boys
${}_a r_{V/A,\,w}$	...	$-\cdot 32 \pm \cdot 14$	$-\cdot 25 \pm \cdot 16$,
${}_a r_{C_V/C_A,\,w}$	...	$-\cdot 12 \pm \cdot 15$	$-\cdot 23 \pm \cdot 16$.

Now the correlations are not very large as compared with their probable errors, but they have *all one sign*, and this is negative. In other words the increase of expenditure on vegetable food relative to the expenditure on animal food, or the increase in the number of calories obtained from vegetable food as compared with the number obtained from animal food is associated in every case with *decreased* weight of the children. Thus we see that as far as any conclusion whatever can be drawn from Miss Lindsay's data, it is directly opposed to her statement that it is better to spend money on oatmeal, peas or beans than on flesh, fish, eggs, etc. She has started with the dogma that a calorie is of equal value whatever its origin, and not stayed to investigate whether it was even justified by her own material. Meanwhile her statement as to oatmeal has gone out as if it were a statistically demonstrated fact, whereas the only conclusion which would be justified in any measure by her data is that the proportion of animal to vegetable food should be kept as high as possible, if weight be taken as a test—although but a partial one—of the efficiency of a diet for a growing child.

The elaborate dietaries carefully worked out by Miss Lindsay are of very small service indeed, because they have not been accompanied by any adequate anthropometric record of the families thus dieted. The present reviewer wrote at once to Miss Lindsay and later to Professor Noel Paton in the hope that it might still be possible to save the situation by some attempt to weigh at least the majority of the members of the families whose diets were recorded. This appears, however, to be no longer possible†, and the result is the not unfamiliar one—an elaborate piece of investigation has been carried out and practically no safe conclusions can be drawn from it. Those concerned in it have not studied beforehand what would be needful statistically to establish an inference, and the sections of the memoir (pp. 28—32) on "The possibility of Improving these Diets" and on "The Relationship of these Diets to Health"—which have been most widely quoted in the popular press—may express either correct or incorrect views; the data provided are wholly insufficient to justify any conclusions at all.

* A little consideration will show that this does not confute the result reached later, because in ${}_a r_{C_A w}$ and ${}_a r_{C_V w}$ no attention is paid to the *relative* amounts of animal and vegetable food.

† A final appeal to Dr Chalmers, since this paper was in type, has resulted in his most kindly attempting all that was possible under the circumstances. Some 64 children of from 5 to 14 years of age have been found and measured, and I hope in the next number of this Journal to revise the above numerical constants on this larger, but still sadly slender material.

II. Note on the Surface of Constant Association.

By KARL PEARSON, F.R.S.

In the recent memoir by Dr Heron and myself a reference was made to the future publication of this note on the surface of constant association, *Biometrika*, Vol. IX, p. 315. The integral equation to the general surface was given, and also the particular form it took, still very complicated, for the simple case of total or 'marginal' frequencies being normal distributions. It was considered worth while to fully analyse one case of such a surface, namely that of $Q=0{\cdot}6$ for Gaussian marginal frequencies. The numerical calculations were carried out by Miss Julia Bell, M.A., and from her ordinates of the sections the sections were plotted by Mr H. E. Soper, M.A. with the aid of a Coradi coordinatograph. By interpolation when needful Mr Soper constructed the isoplethes of this surface of constant association, and also an excellent card model, for comparison with the model of a normal surface. The chief features of this surface were referred to in the paper just cited. Although the marginal frequencies are symmetrical, the cross sections are skew-curves, the skewness increasing from zero for the central section to ·16 for the y-array when $x=1{\cdot}5\sigma_x$ and to ·20 for the y-array when $x=3{\cdot}5\sigma_x$.

Diagram I gives the series of sections on one side of the mid-section $x=0$ up to $x=3{\cdot}5\sigma_x$ by intervals of $0{\cdot}25\sigma_x$; the same sections are repeated in inverse order on the other side of the central section $x=0$. It will be seen at once from the indicated means how skew the sections are.

Diagram II gives the isoplethes or contour-lines of equal frequency. They are approximately but not accurately ellipses with common principal axial directions, but they are very far indeed from being *similar* ellipses. In the contour corresponding to $z=\frac{9}{10}$ of its maximum value, the major axis is considerably more than twice the minor axis of the oval; in the contour corresponding to $z=\frac{1}{10}$, the major axis is very much less than twice the minor; the ovals tend indeed to less and less ellipticity. On this diagram are also plotted the regression lines of means and of modes. It will be seen that they tend to become parallel to the axis of x, or the regression tends to become zero. There is little doubt, that quite apart from normality of the marginal frequencies, any symmetrical marginal frequency would lead to like results, i.e. the isoplethes would not be similar curves, and the regression would be skew, and tend to asymptote to the horizontal. Thus the constancy of association would depend for its application on the existence of material in which the variates would be intimately related near their mean values and cease to have any relation towards extreme values. Intervening values would exhibit every variety of relationship, from the maximum in the neighbourhood of the means to zero value towards the extremes. These properties of the surface explain why Q is not even approximately constant, for those numerous surfaces of statistical practice in which the regression is approximately constant, i.e. linear.

Plates XXX, I (*a*) and (*b*), XXXI, I (*c*) give photographs of the actual model surface. In Fig. I (*a*) we see the surface 'end on' to one set of cross-sections and we grasp readily the skewness of the cross-sections and its increasing value as we pass from the central section. Fig. I (*b*) indicates by the verticals the regression line of means; these verticals have their feet on the regression line and the eye sees at once by their closer and closer approximation to each other, the deviation from linearity. Fig. I (*c*) gives a diagonal view of the surface of constant association, and underneath it Fig. II (*d*) has been placed a model of the Gaussian surface* of constant regression for comparison; the angle of deviation was taken roughly about 60°, to give a surface of correlation 0·5. Except for the regression line and skew-sections in Fig. I, the eye does not distinguish very readily in these photographs of Figs. I and II, the fundamental differences of the two surfaces which appear so markedly in the isoplethes of Diagram II.

* On the Brill system of interlaced sections.

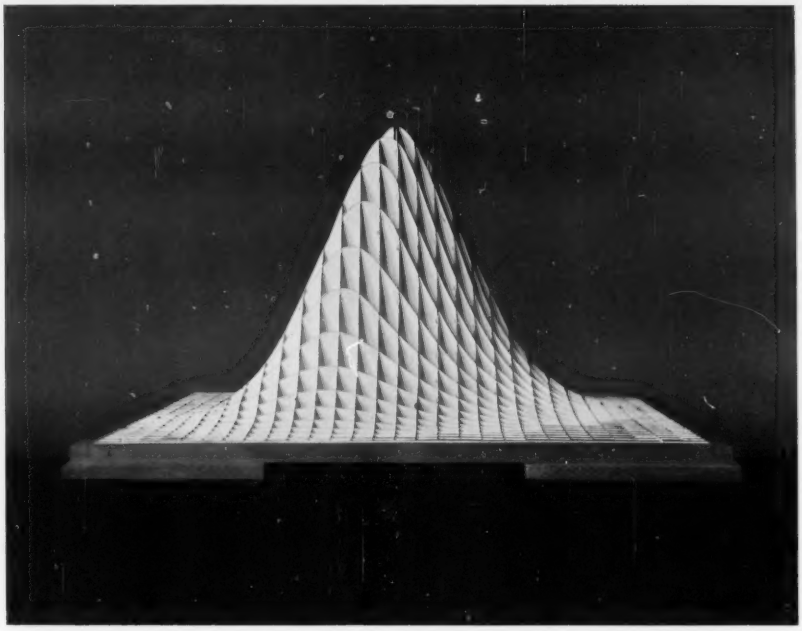


FIG. I (*a*). Surface of Constant Association.

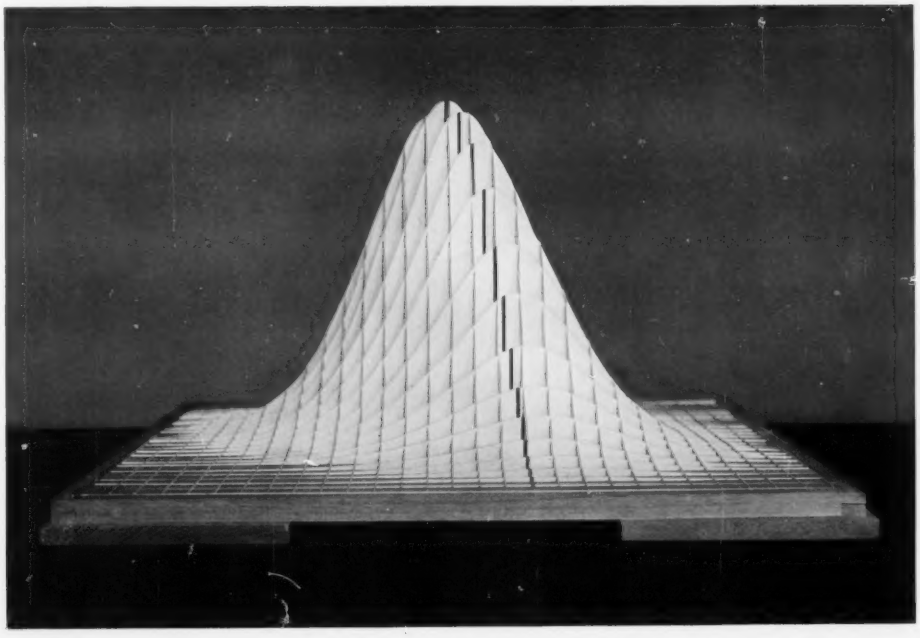


FIG. I (*b*). Surface of Constant Association.

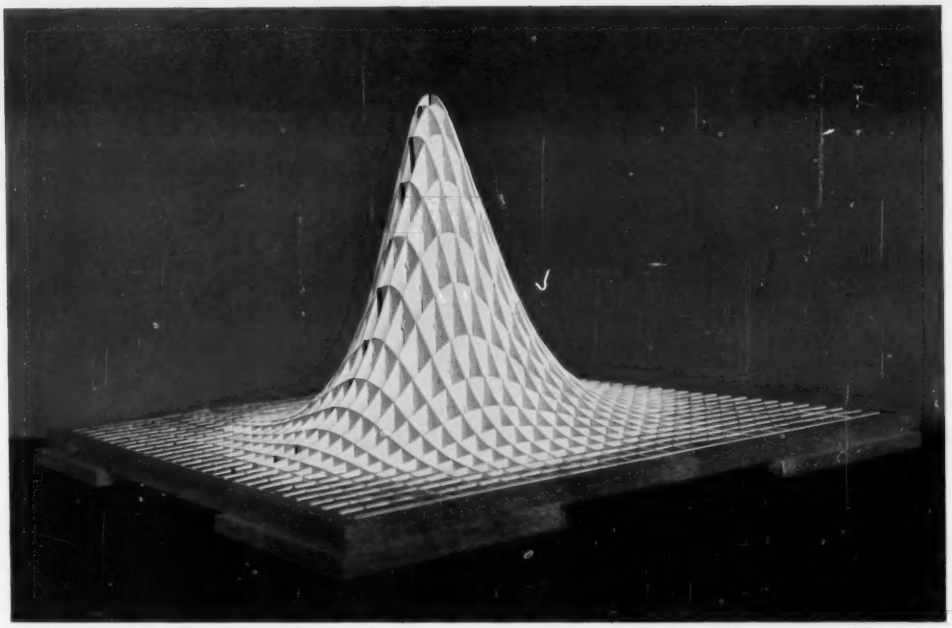


FIG. I (*c*). Surface of Constant Association.

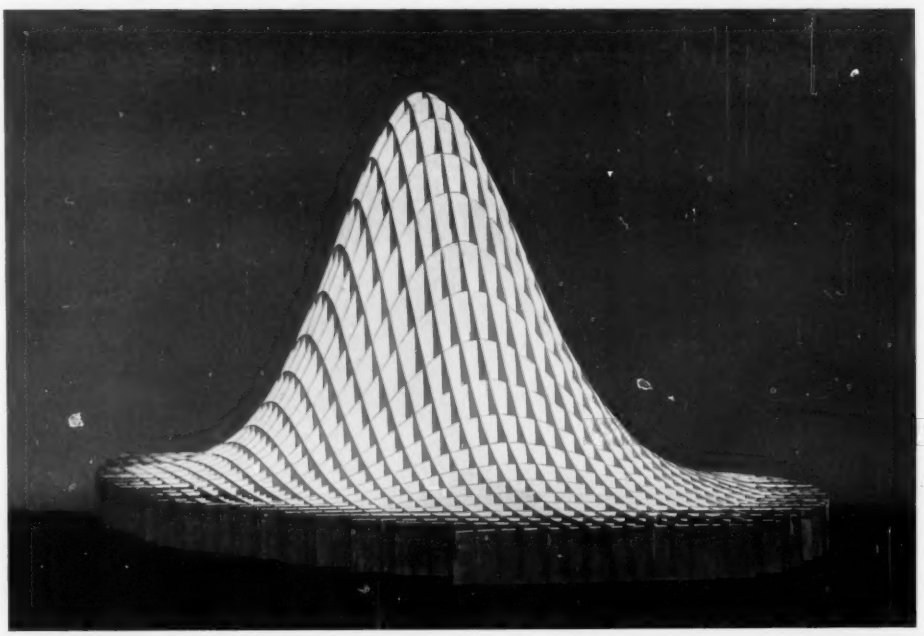
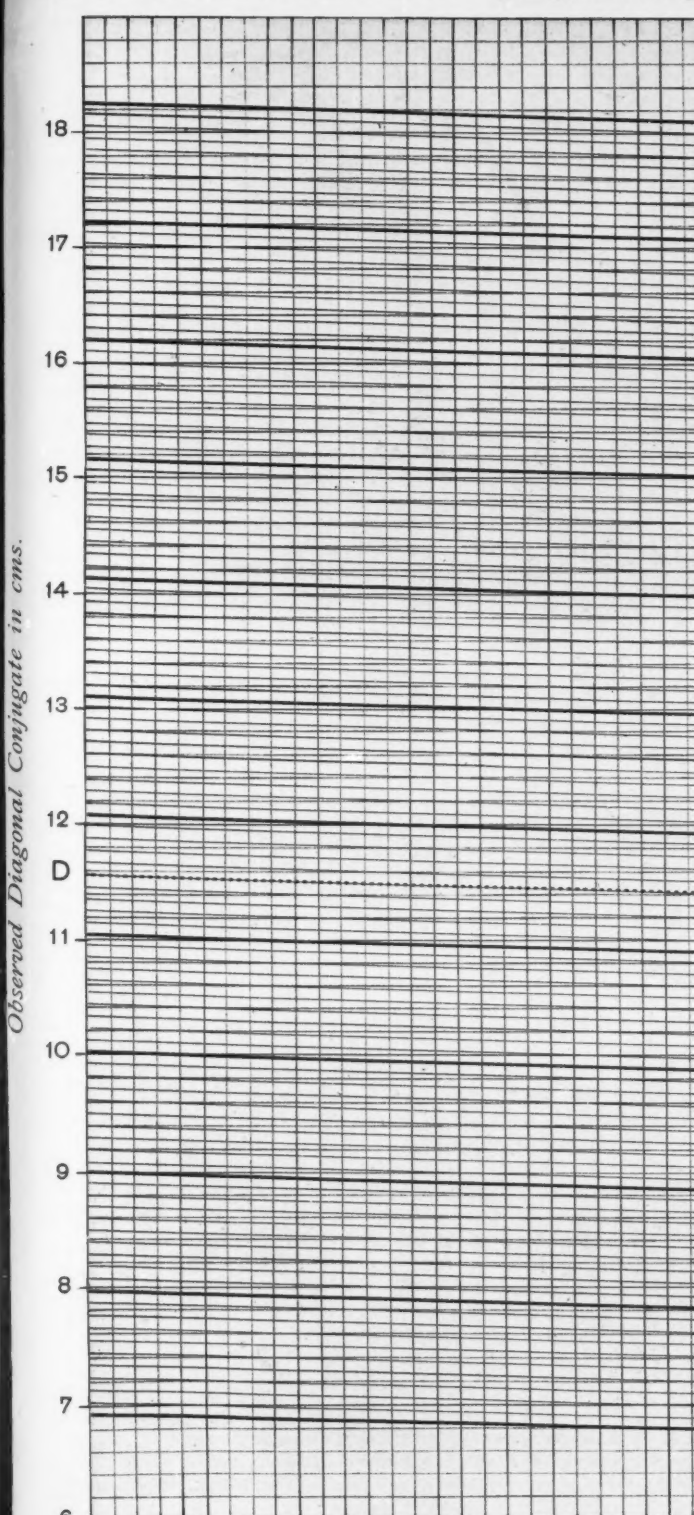


FIG. II (*d*). Brill type model of Gaussian surface.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Observed Diagonal Conjugate in cms.
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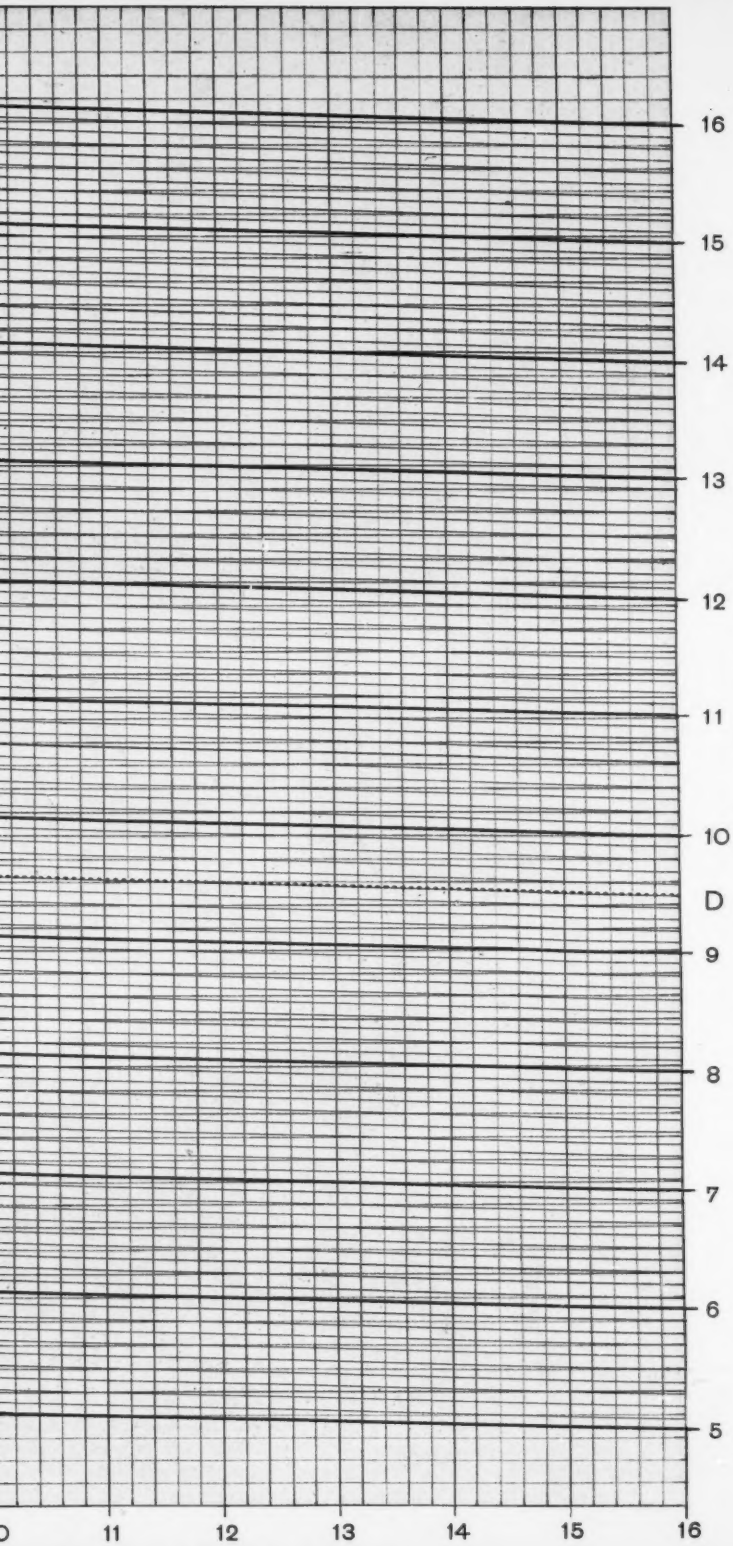
Observed Antero-Posteri

STETRICIAN'S ABAC I.

Plate XXXII.



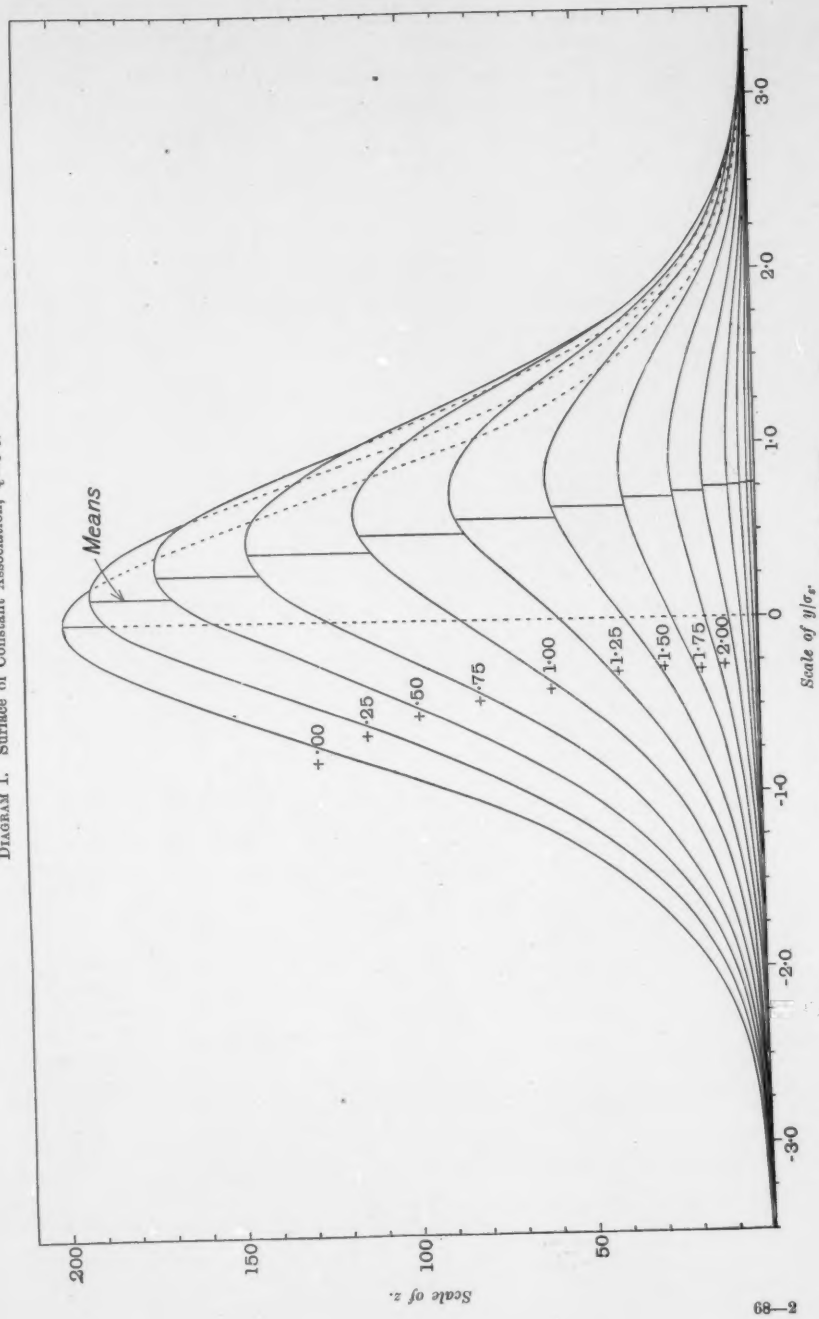


DIAGRAM I. Surface of Constant Association, $Q=0{\cdot}6$.
Showing skew-sections at intervals of $x=0{\cdot}25\sigma_x$.

The equation to the surface of $Q=0{\cdot}6$ with normal marginal frequencies, for a total population of 1000, is :

$$z=\frac{4000\frac{dp}{dx}\frac{dq}{dy}(1+3(p+q)-6pq)}{\{(1+3(p+q))^2-48pq\}^{\frac{3}{2}}},$$

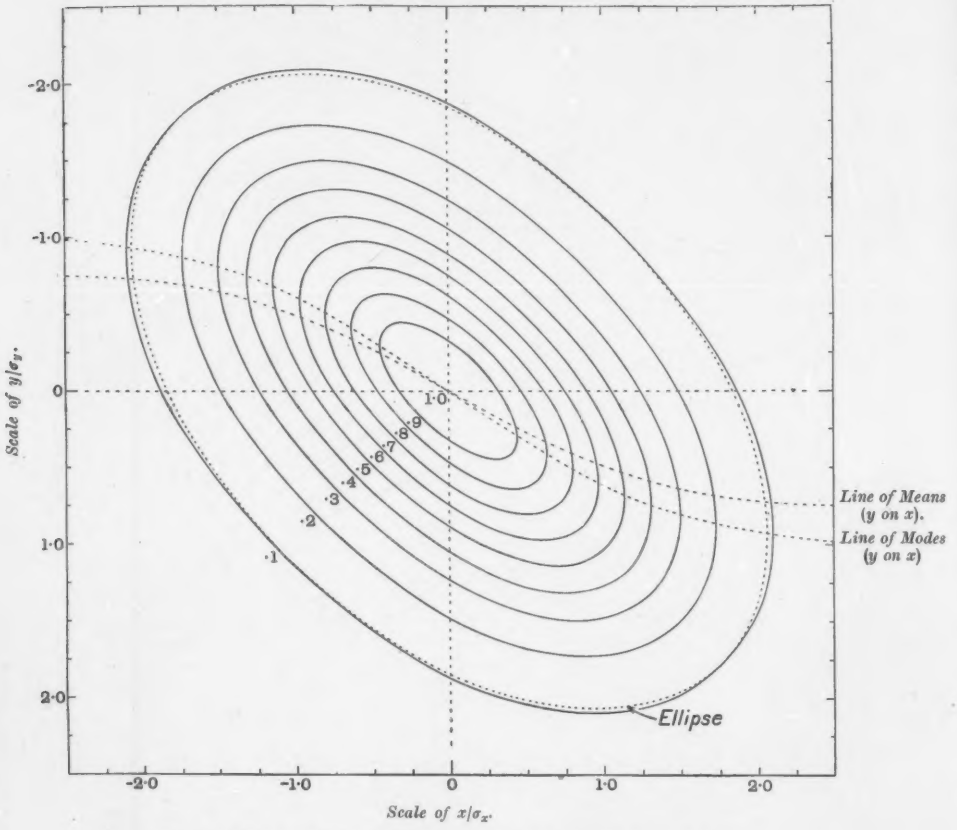
where

$$p=\tfrac{1}{2}(1+a) \text{ for } x/\sigma_x,$$

$$q=\tfrac{1}{2}(1+a') \text{ for } y/\sigma_y,$$

a having the usual significance attributed to it in Tables of the Probability Integral, e.g. Sheppard's.

DIAGRAM II. Isoplethes of Surface of Constant Association, $Q=0{\cdot}6$.



The isoplethes are drawn for each tenth of the maximum value of z.

The following short table will be sufficient to indicate the nature of the cross-sections to anyone wishing to pursue the matter further.

z-ordinates of y-arrays for given special values of x/σ_x.

Array at $x/\sigma_x =$

Values of y/σ_y.	0·0	0·5	1·0	1·5	2·0	2·5	3·0	3·5
3·5	0·223	0·332	0·388	0·314	0·165	0·059	0·015	0·003
3·0	1·135	1·688	1·970	1·589	0·834	0·297	0·077	0·015
2·5	4·536	6·736	7·811	6·223	3·230	1·145	0·297	0·059
2·0	14·881	21·381	24·195	18·497	9·269	3·230	0·834	0·165
1·5	38·080	55·053	57·904	39·890	18·497	6·223	1·589	0·314
1·0	85·096	113·670	100·499	57·904	24·195	7·811	1·970	0·388
0·5	155·888	168·289	113·670	55·053	21·381	6·736	1·688	0·332
0·0	198·944	155·888	85·096	38·080	14·881	4·536	1·135	0·223
−0·5	155·888	97·562	49·567	22·036	8·414	2·644	0·662	0·130
−1·0	85·096	49·567	25·217	11·369	4·379	1·381	0·346	0·068
−1·5	38·080	22·036	11·369	5·186	2·010	0·635	0·159	0·031
−2·0	14·881	8·414	4·379	2·010	0·781	0·247	0·062	0·012
−2·5	4·536	2·644	1·381	0·635	0·247	0·078	0·020	0·004
−3·0	1·135	0·662	0·346	0·159	0·062	0·020	0·005	0·001
−3·5	0·223	0·130	0·068	0·031	0·012	0·004	0·001	0·000
Means	0·000	0·268	0·494	0·646	0·723	0·757	0·766	0·769

III.

Studies in the Meaning and Relationships of Birth and Death Rates. I. The Relationship between "corrected" Death-rates and Life Table Death-rates, by JOHN BROWNLEE, M.D., D.Sc. Journal of Hygiene, Vol. XIII. No. 2, pp. 178—190.

There are three "death-rates" used by those who deal with the statistics of public health etc.; the "crude" death-rate found by dividing the total number of deaths in a district in one year by the total number of inhabitants; the "corrected" death-rate found by applying the death-rates for age and sex to a standard population and calculating the rate from the figures so found; and the "life table" death-rate which is the rate that would be found by working out a complete stationary population from the death-rates for each age and calculating the ratio of the total deaths among the assumed stationary population to the total stationary population. This result is simply the reciprocal of the "expectation of life" at birth. Dr Brownlee thinks that this last measure is the most satisfactory death-rate and his paper is an attempt to reach approximate values for it from the corrected death-rates. Although Dr Brownlee does not set them out in that way these approximations appear to be based on the use of an imaginary stationary population or populations and require, we think, to be tested more extensively than has yet been done before they are used for any practical conclusions.

It appears to us that the use of the "expectation of life" at birth or of a single death-rate for a population as a whole cannot, however it is calculated, gauge completely the mortality of that population, and cannot therefore form an entirely satisfactory basis for comparative purposes: two populations may show the same death-rate or expectation of life and yet the mortality of one of them may, for instance, be heavy only in the first five years of life, while the other is light for the first five years but heavy at later ages. There must therefore be limitations in the use of any single figure, and if more than one figure is used we do not see why the death-rates at various ages should not be employed as they stand. They are easier to interpret and no more difficult to deal with than the expectation of life at a series of ages,—an alternative measure implied by Dr Brownlee.

In the paper before us Dr Brownlee mentions that further work is to follow, and possibly it will show how he intends to overcome these difficulties. W. P. E.

IV. A Case of Familial Malformation in a Fowl's Head.

By HUBERT M. TURNBULL, M.D., Director of the Pathological Institute of the London Hospital.

S.D. 2105, 1912. *Fowl's head received from Mr Roxburgh, 10th October*, 1912.

The breeder says that another chicken of the same brood has a similar deformity. Fowl examined turned out to be the heaviest of the whole brood, in spite of its crooked beak.

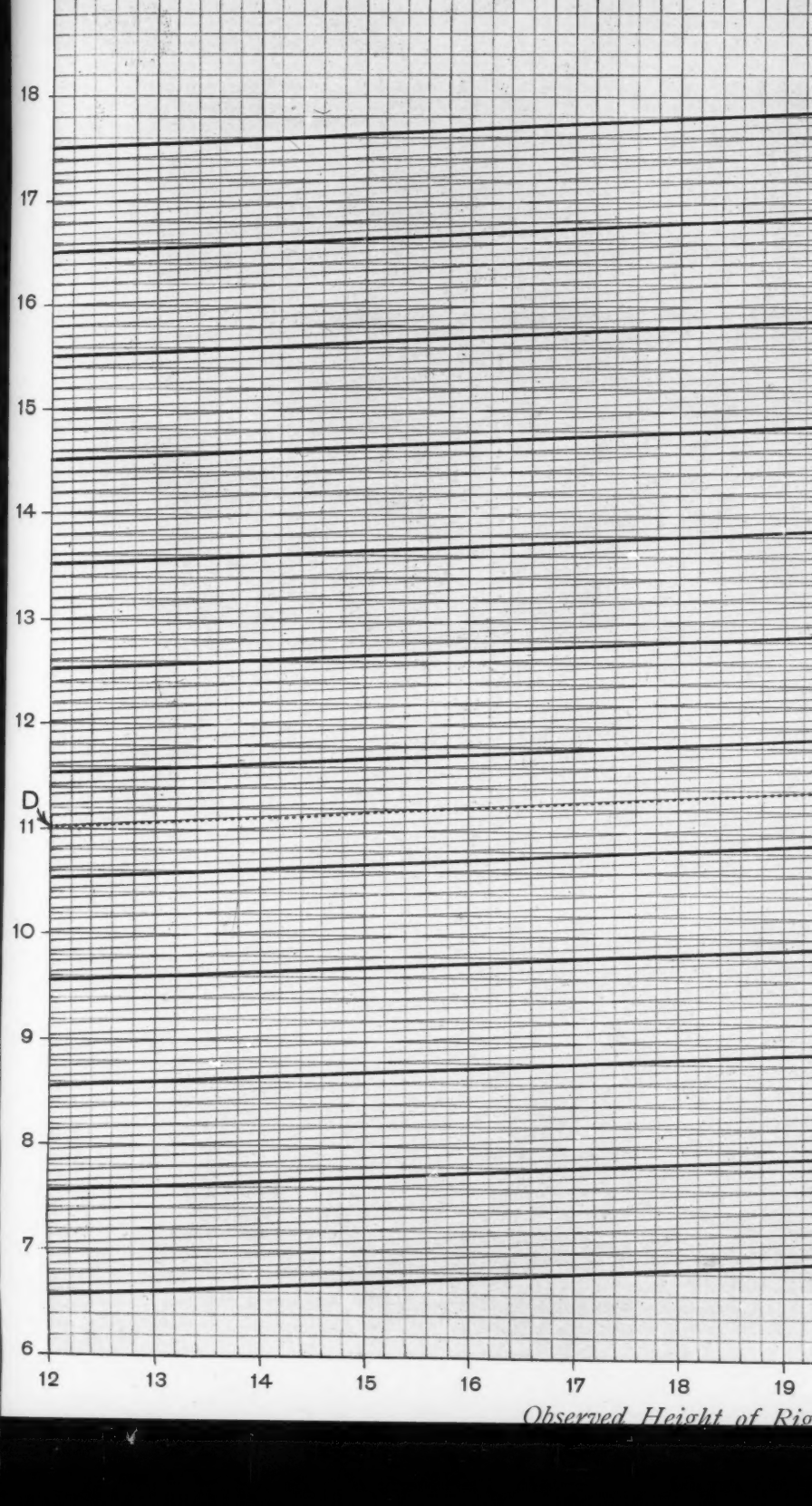
External appearance. Head and neck of domestic fowl, ?cock. Wattles are red and symmetrical. Flat, tongue-like, red comb. Eyes are of equal size. Above the nostril on the left side there is a semilunar cartilage 1·5 cms. long and 0·5 cm. from above down; nostril is 2·1 cms. from the anterior canthus. Right nostril is 1·3 from anterior canthus; semilunar cartilage is 0·5 by 0·3 cm. Nostrils on both sides are 2 cms. from the angle of the mouth. Horny beak starts on the left side 2·3 cms. from the angle of the mouth, on the right side 1 cm. from the angle. As a result the superior mandible on the left side is convex and the upper beak is twisted over to the right so that its point lies 0·2 cm. to the right of the right border of the lower beak, at a point 0·7 cm. from the end of the latter. The upper jaw and the beak on the right side form a sharp concavity. The anterior border of the orbit on the left side appears much farther back than on the right. Tongue is quite symmetrical. On the roof of the mouth the palate is divided into three divisions, one side having been cut longitudinally. The anterior part of the palate corresponding to the beak is not divided. This portion is deflected with the beak to the right side.

The chief alteration in the soft parts is the small size of the right nostril and its operculum. A longitudinal incision had been made, in killing the fowl, through the palate to the left of the middle line.

I. View of skull from above. Traced from a photograph.
N = Nasal bones.
F = Frontal bones.

III. View of skull from right side. Traced from a photograph.

II. View of skull from below. Traced from a photograph. Left palatal and pterygoid bones severed.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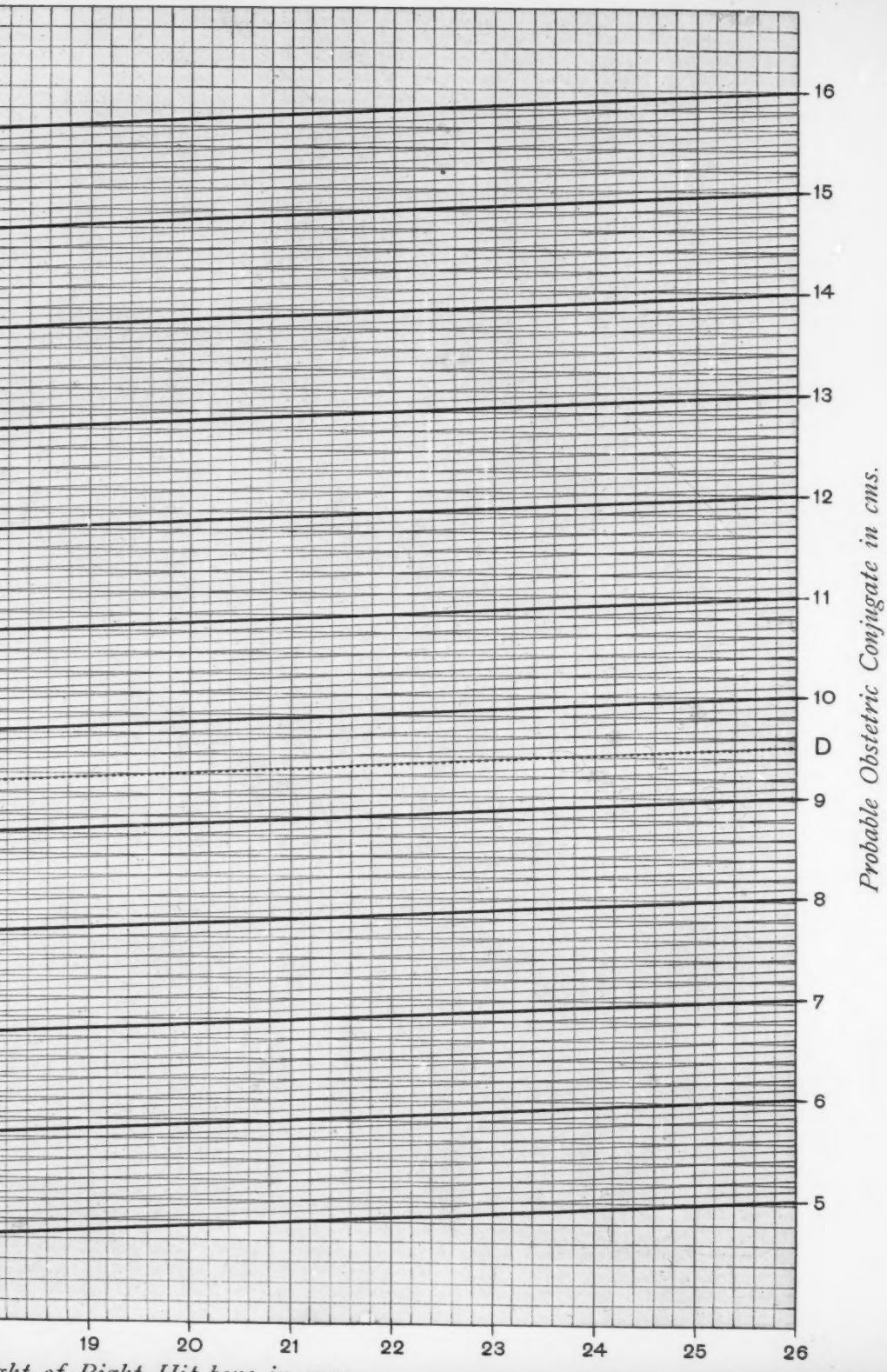
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Probable Obstetric Conjugate in cms.
ght of Right Hip-bone in cms

The head was simmered for five hours and the flesh removed with forceps. Partially cleaned in alcohol and chloroform—equal parts.

Skeleton. The incision in the palate has severed the left palatal and pterygoid bones close to their articulation with the vomer and rostrum. The right nostril measures 0·7 cm. long by 1 cm. high, the left 2 by 0·7 cm. The right frontal anterior to the posterior limit of the orbit is 3 cms. long and from a breadth posteriorly of 1 cm. tapers gradually; its anterior extremity appears to be of denser structure than that of the left frontal, and is devoid of a process mesial to the nasal bone. The left frontal is 2 cms. long and maintains a breadth of about 1 cm. This asymmetry throws the anterior part of the skull a little to the left. The superior surface of the right nasal bone measures 2·3 by 0·5 cms., the left 2·6 by 0·7 cms.; the lateral process of the right nasal does not share in the hypoplasia. The left nasal bone is thin and translucent, the right is thick and opaque. The right jugular and quadrato-jugular measure 4 cms. as against 4·2 cms. on the left. The right superior maxilla appears to be smaller than the left. The shortening of these bones on the right side bends the fore part of the face and beak sharply to the right. The other bones are symmetrical.

The narrow right frontal may be the result of hypoplasia of the right olfactory bulb, in consequence of which the soft and bony parts of the right nose may have failed to develop. This theory, however, does not give a satisfactory explanation of the elongation of the right frontal, the absence of its process mesial to the nasal bone, and the sclerosis of the right nasal bone. A more satisfactory explanation of the deformity is that it is the result of a hypoplasia of the right nasal bone, the elongation of the right frontal illustrating the inter-dependence of growing structures. The sclerosis of the right nasal bone, and apparently also of the external frontal process with which it articulates, suggest that the arrest in development has been caused by inflammation or trauma. The absence of the mesial process of the frontal may be due to involvement of the tissue in which it is formed, in such inflammation or trauma.

V. Note on a Ready Reckoner for the Obstetrician.

EDITORIAL.

On p. 503 of this volume of *Biometrika* two formulae are given by Dr de Souza, namely: (c') for determining the most probable value of the obstetric conjugate in terms of the known values of the diagonal conjugate and of the antero-posterior diameter, and further (i') giving the most probable value of the obstetric conjugate as deduced from the known values of the diagonal conjugate and of the height of the right hip-bone. It was proposed to include in Dr de Souza's paper two abacs or ready reckoners for the use of the obstetrician, so that after measuring on the living subject the diagonal conjugate and either the antero-posterior diameter or the height of the right hip-bone, he could read off from them the probable value of the obstetric conjugate without any calculation. These abacs were prepared by Miss H Gertrude Jones, but owing to certain difficulties of engraving, it was not found possible to delay the printing off of Dr de Souza's paper till they were completed. The two abacs have only reached us, in but moderately successful reproduction just as we go to press, and are included in this final note.

The method of using them is extremely simple. For example, in the case of Abac I, Plate XXXII, suppose the observed antero-posterior diameter to be 11·7 cms. and the diagonal conjugate to be 13·4 cms. we move upwards between the vertical lines at 11·6 and 11·8 on the antero-posterior diameter scale, until we meet the horizontal line at 13·4 cm. on the diagonal conjugate scale; we then pass off on the nearest sloping line to the scale of the obstetric

conjugate: the required sloping line lies between the 11·4 and 11·5 obstetric conjugate lines or the probable value of the obstetric conjugate is 11·45 cms. The actual value found from Dr de Souza's formula (c') is 11·43 cms. If the vertical antero-posterior diameter line and the horizontal diagonal conjugate line intersect in any case below *DD*, there is possibility of difficulty in labour.

Again, if the diagonal conjugate be 13·4 and the height of the right hip-bone 20·7 cms., we enter by the vertical line at 20·7 on the right hip-bone scale of Abac II, Plate XX[illegible], and the horizontal line on the diagonal conjugate scale at 13·4 and find that they meet on the sloping obstetric conjugate line of 11·45 cms. The actual value as found from formula (c') is 11·44. The line of possible difficulty in labour is indicated by *DD*. The use of a lens may occasionally be of assistance, but most obstetricians will find themselves able to read the value of the probable obstetric conjugate to at least a millimetre and with a probable error of 3 mm., this is ample. Descriptions of the methods of measuring the required lengths on the living will be found in Dr de Souza's paper.

ADDENDUM. *Deformity known as Split-Foot, Biometrika*, Vol. IX. p. 385.

Annie Eliza S. (Mrs F.) IV. 9, has given birth a few days ago to a female child, quite normal in every respect, October 22, 1913.

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